HOW ARE ENGINEERING ETHICS INTEGRATED INTO HIGH SCHOOL EDUCATION IN COLORADO?

by

Jake Walker Lewis

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Angela R. Bielefeldt

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Daniel Knight

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Fernando Rosario-Ortiz

Date_______________

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

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Lewis, Jake Walker (M.S., Civil, Environmental, and Architectural Engineering)

How are engineering ethics integrated into high school education in Colorado?

Thesis directed by Professor Angela Bielefeldt

Engineering education continues to become more prominent in Colorado high schools through dedicated courses, integrated into other STEM courses (such as science and mathematics), and/or extracurricular activities. An important topic within engineering is ethics. This broad subject includes macroethical issues, such as the environmental and societal impacts of engineering and technology. However, engineering ethics education in high school has not been widely characterized. This research therefore examines if and how engineering ethics are being implemented in high school engineering education, seeking to understand the teacher perspective. This qualitative research was conducted by interviewing 14 high school teachers in Colorado. These teachers represent multiple STEM subjects, school districts, public and private institutions, as well as religious and nonsectarian institutions. The results of this study detailed how most STEM-based teachers integrate engineering ethical issues, although some appear not to recognize this. This may be because most teacher interviewees viewed environmental and societal impacts as being different from ethics. Furthermore, most teachers believed this integration to be important in K12 education. Additionally, each teacher interviewee was able to identify at least one obstacle to engineering ethics integration. The seven emergent obstacles, classified as either challenges or barriers per individual identification, were represented across teacher perspectives. It should be noted that these results may not apply to a broader study.

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1. Introduction

The need for qualified and capable engineers has continued to grow as expectations placed on them have adapted to the needs of society. These engineers are faced with ever-evolving problems which impact people, the environment, and society itself. It is critically important, therefore, that these issues are faced by trained engineers. These engineers represent the full spectrum of engineering, from electrical to mechanical, chemical to civil, yet all began their path somewhere towards becoming a qualified engineering. For many engineers, their path begins at the start of their postsecondary education, and their interest and passion in engineering may have originated during their Kindergarten through 12^{th} grade (K12) experience. From prior research conducted, it was determined that few students transfer to engineering degrees from other majors in college (Ohland et al., 2008), prompting the consideration of what importance K12 educational programs have on the development of future engineers. Engaging with K12 students, through either enticing students to take their first engineering course or encouraging them to establish an interest in engineering through science or mathematics, has led these students to seek out engineering majors in college and represents a notable portion of the greater field of engineering subjects.

Although an increasing body of literature documents detail engineering integration in high school education, there is a notable lack of information regarding engineering ethics implemented in these programs. The ethical development of engineers is an important part of what makes an engineer qualified to be considered such, one who understands the weight of their role, and the impacts their practice may have. This led to the question, “What is being done in high school engineering programs regarding ethics?" This research study examined how K12 engineering education is implementing ethics through interviewing high school teachers representing both engineering and non-engineering, STEM-based, fields.

This research study was informed by a prior understanding of the implementation of ethical topics in engineering education within a higher education setting. Having been involved with a pre-engineering program as a high school student, one that ultimately led me to pursue engineering in higher education, I recall an ethics-based unit leaving a strong impression on me. After getting engaged with qualitative research regarding ethics in postsecondary engineering education through a summer program as an undergraduate, I decided to construct my thesis to examine ethics in engineering education in Colorado high schools.

There has been a growing focus on science, technology, engineering, and mathematics (STEM) education in the K12 setting. (NAE, 2018). High school students may be exposed to engineering (and STEM topics as a whole) through curriculum and/or extracurricular activities. Students at public institutions may be required to take a certain number of mathematics and science courses to fulfill graduation requirements, with engineering courses typically considered as electives (NAE, 2013). Educational standards vary across different states, and while there are the Colorado Career and Technical Education (CTE) standards that includes STEM and Design & Information Technology topics, there are not explicit engineering education standards similar to the mathematics and science standards ("CTE Standards and Program Approval," n.d.). Furthermore, public school districts may add further regulations to the schools they encompass ("Graduation Guidelines FAQs | CDE," n.d.). In non-engineering courses, but still STEM-based, engineering topics may be introduced. Some examples may be problem solving being incorporated into an environmental science project about providing clean water to a struggling population, or an iterative design cycle regarding a catapult being designed in a physics class. In addition, some private institutions and/or states may require engineering courses to be taken in order to graduate (“The Best STEM High Schools in America,” n.d.).

Whether a class is explicitly engineering based or promotes engineering topics and thinking within a non-engineering course, students will begin to construct their own understanding of what engineering is and the role of an engineer. This construction will be influenced by the teachers, who design the learning environments around engineering topics. Both explicit curriculum and hidden, or null, curriculum (what is not taught) are important in education (Polmear, Bielefeldt, Knight, Swan, & Canney, 2019). Thus, it is important to study high school teachers engaged in engineering education, or another STEM subject that may incorporate engineering topics, to determine if and how ethical and societal impacts are integrated. To assess how ethical considerations are taught to high school students, the process of interviewing teachers was identified as the best qualitative research method.

This thesis presents my research study conducted to examine the integration of ethical issues into high school STEM education. Following this introduction to the study, a literature review is provided. This section will detail what the study is based on, how it is supported by existing research work, and any limitations in the literature review itself. The methods section describes the qualitative research approach used in this study. This includes detailing the methods used to recruit teachers to participate in the study, the interview process, and creating and analyzing teacher interviewee transcriptions. The results are then presented to answer each of the four research questions defined at the end of this section. This includes tables and figures that describe the context of the teachers and schools represented in the study. Example quotes from edited transcripts are provided and used to show the range of teacher perspectives. This includes obstacles to ethics incorporation that were identified by teacher interviewees; these obstacles were defined as either a challenge (possible to overcome) or barrier (currently impassable) for each case of identification depending on interpreted evidence from the teacher interviewee. A flowchart was developed as the final iteration regarding qualitative analysis, with each teacher assigned one of four codes reflecting their personal understanding of ethics and how their understanding matches the understanding of the research team. The conclusions section of this thesis details the conclusions made with regards to the research questions, ideas for future work, and a closing statement on the research study and implications. Finally, the appendices include research work referenced, such as the IRB approval letter for the study (Appendix A), the semi-structured interview script (Appendix E), an example rough and edited transcription (Appendix F), and the first two iterations of the qualitative coding process (Appendix G and Appendix H).

The four research questions are defined below and detail the overall goals of this study:

1. Do high school teachers engaged with engineering/STEM incorporate engineering environmental and societal impacts in their teaching, and if so, how?

2. Do high school teachers engaged with engineering/STEM incorporate ethics in their teaching, and if so, how? Furthermore, how do they define ethics with regards to EESI or any other factor?

3. How do high school teachers engaged with engineering/STEM view the importance of environmental/societal impacts and/or ethics integration?

4. What obstacles are perceived by high school teachers to integrating environmental/societal impacts and/or ethics?

2. Literature Review

The literature review was separated into seven parts: (1) how engineering ethics and societal impacts (EESI) has been defined, (2) the importance of EESI, (3) the integration of engineering in K12 settings, (4) teaching standards in K12 STEM education, (5) evidence of EESI integration in K12 education, (6) lessons from EESI integration in higher education, and (7) the Colorado context. Additionally, limitations in the literature review were discussed identifying a lack of research regarding ethics implementation in K12 engineering education.

2.1 Definition of engineering ethics

The concept of engineering ethics pertains to ethical topics and/or discussion within engineering and its many fields. The standard definition of ethics, also known as ethical standards, may be described as "Morality stated as principles. Intended to generate trust, good behavior, fairness, and kindness. Typically occurs in a corporate setting, for an organization." ("What is ETHICAL STANDARDS?," 2012). Individuals may think about these types of ethics when prompted, such as the teachers in this study, however there are also profession-specific definitions of ethics. Engineering ethics falls under "professional ethics", similarly to medical doctors and lawyers. These ethics are one of the fundamental characteristics of a profession (Butterman, 2014). Engineers may face these topics when practicing in their field. There may even be ethical considerations that they face on their way to becoming an engineer. Engineering ethics can be subdivided into two categories: macroethics and microethics (Herkert, 2005). Macroethics pertains to the social responsibilities of the engineering profession as a whole, and how their decisions have implications for society. An example of a macroethical topic in engineering would be the consideration of sustainable design. However, microethics pertains to the responsibilities of the individual engineer, and the direct causality of their actions. An example of a microethical topic would be the forging of calculations regarding a sponsored research study.

Ethical responsibilities of engineers are also defined by codes of ethics. These codes help ensure that engineers exhibit the highest standards of honesty and integrity. The National Society of Professional Engineers (NSPE) has a defined code of ethics to which all members of the engineering profession are expected to adhere to ("Code of Ethics | National Society of Professional Engineers," 2019). However, since engineering is a diverse profession, professional societies associated with different disciplines have separate codes of ethics ("Code of Ethics | ASCE," 2017). Although these codes vary, all of them put human safety first. Codes of ethics also vary geographically, such as the European Federation of National Engineering Association's (FEANI) Code of Conduct ("FEANI position paper on Code of Conduct: Ethics and Conduct of Professional Engineers," 2006). Additionally, codes of ethics have evolved over time reflecting changes in society's expectations of engineering. For example, 'sustainability' was added to the ASCE code on November 1st, 2008 ("Development of Sustainability Provisions in ASCE Code of Ethics | ASCE," 2008). Even more recently in 2017, 'treat all persons fairly' was added ("Board Adopts New Canon for ASCE Code of Ethics | ASCE News," 2017). Thus, engineering ethics embeds issues of environmental and societal impacts. The nature of environmental/societal impacts embedded within engineering will be further discussed latter in this literature regarding the goals of the study.

2.2 Importance of ethical and societal impacts for engineers

During engineering education, deliberate ethical development in the student is critical. Over the course of their career, engineers may encounter diverse systems such as individuals, the environment, and society at large. Their solutions to address issues they face will have impacts that may be ethical in nature. By developing ethically-conscious engineers, not only will they be able to identify ethical issues that present themselves in engineering, they will have the foundations of reaching an informed decision regarding this ethical issue. Furthermore, the public, who are impacted by the various fields of engineering, places great trust on engineers to practice in a consciousness and informed manner.

In recognition of the importance of ethics, national and international bodies that accredit engineering programs have requirements that ethics be taught and/or learned by students. In postsecondary engineering education in the United States, ABET (formerly the Accreditation Board for Engineering and Technology) sets the standards for accreditation (ABET, 2019). ABET accreditation requires that students graduate with competencies that includes ethical topics. Previously, ABET had the A-K criteria, where only two of the outcome criteria regarded ethics (ABET, 2016). This was expanded upon in the current ABET criteria. For example, under criterion 3, titled ‘student outcomes’, outcome 4 requires “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” (ABET, 2019). This brought together what were previously (2000-2017) separate outcomes “f. an understanding of professional and ethical responsibility” and “h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.” (ABET, 2019). Ethical development in engineers is a preventative measure in addressing the consequences of their actions, where by if they are able to identify and address ethical issues in their work, the possible negative impacts may be avoided. This study will focus on engineering ethics and societal impacts (EESI) implementation in K12 education; it should be noted that EESI embeds environmental and societal impacts.

Beyond the requirements for ethics education, there are requirements for ethical practice among engineering professionals. In order to become a licensed engineer in the U.S., individuals must pass two examinations, the NCEES Fundamentals of Engineering (FE) and Principles and Practice of Engineering (PE) examinations. Both of these examinations include questions regarding ethics. For example, the FE exam for environmental engineering has between 5 to 9 questions on ethics and professional practice, covering the codes of ethics, contracts, legal considerations, professional liability, public protection issues, and regulations (“NCEES FE exam information,” 2019). Most states have additional requirements regarding ethical practice, such as requiring letters of reference that attest to the character of potentially licensed engineers (“Professional Engineer Engagement Record and Reference Form,” 2019; “Professional Engineer Reference Form;” 2019; “Code of Colorado Regulations,” 2019). Additionally, some states require that applicants take a separate ethics-specific examination, such as the Texas Ethics of Engineering Exam (“Texas Board of Professional Engineers and Land Surveyors,” n.d.). Furthermore, 34 states require continuing education to maintain an engineering license, and 12 of these states require what is known as ethics hours (“Professional Engineering CE Requirements by State,” n.d.). Individuals may lose their license to practice engineering if found to be in violation of ethical standards.

2.3 Integration of engineering into K12 education

Regarding K12 students, there are multiple approaches for having them engage with engineering. Beyond engaging and retaining students in engineering education, related topics may be presented in non-engineering courses. From the National Academy of Engineering (NAE), the Committee on K-12 Engineering Education was established in 2006 to address multiple issues such as “how engineering should be taught in K12 education.” The NAE has established three general principles to K12 engineering education (“The Bridge Linking Engineering and Society,” 2009).

First, there are students who may already have an interest in engineering. These students are important to consider as their interest in engineering must be retained as they go through their K12 education. This may be accomplished through providing the students with concepts or challenges that continue to promote this interest. To attract K12 students into engineering, STEM-based courses may implement engineering topics. These engineering topics may encompass design, problem solving, and critical thinking to name a few skills that pertain to engineering as a whole. The implementation of these topics can lead interested students towards an explicit engineering course. There is also the possibility that students are introduced to engineering in an extracurricular environment, such as a club, that leads them to pursue engineering. Some examples may be robotics, environmental, and design competition clubs. College engineering programs encourage this integration through examples of outreach.

Engineering courses are primarily electives within a K12 setting, with a few exceptions from charter and private institutions. High school engineering courses may be established in a variety of ways, from the individual teachers, district assistance, or even through purchasing courses from higher education institutions. There is currently no Advanced Placement (AP) engineering exam, although there is the consideration of implementing such (Rogers, Hennessey, Buxner, & Baygents, 2015). There is also the possibility that K12 engineering teachers may utilize public lessons in preparing their curriculum, such as TeachEngineering, which is a public library of lesson modules created in part by the University of Colorado and utilized by various instructors (Virani, 2012; Pinnell, 2013).

There is evidence that the ABET accreditation policies for engineering in higher education are affecting K12 engineering education, notably high school students (Albright, 2015; Farmer, 2012; Oakes, 2012). Moreover, it seems that ABET policies influence similar curriculum regarding STEM pedagogy in K12 education (Wang, 2011; Moore, 2012; Moore, 2013). ABET further influences K12 education through the concept of “sustainable education” and how the two levels of education are critically linked (ABET, 2018). This term describes how the concept of sustainability is critical to broadening student perspectives, which they carry from the K12 setting into higher education.

2.4 Teaching standards in STEM education for the K12 setting

There are multiple sources of teaching standards in K12 STEM education. The primary standards are those on the federal and state levels, which goes beyond STEM to cover K12 in general. To begin, STEM standards include the “No Child Left Behind”

(NCLB) law in the “Elementary and Secondary Education Act” (ESEA), which detailed K12 general education in the U.S. from 2002 to 2015, which held schools responsible for how students learned (“No Child Left Behind,” n.d.; “New ‘No Child Left Behind’ Aims to Strengthen K-12 STEM Education,” 2015). This law was criticized for how school funding was linked to student performance on standardized tests, and topics not on these tests were deemphasized (“NSTA News,” 2012). Following this, the “Every Student Succeeds Act” (ESSA) was approved for 2017-2021 and aims to provide equal opportunity for students, including those with special education services (“Every Student Succeeds Act (ESSA) | U.S. Department of Education,” n.d.). There is established ethics education in K12 settings, notably academic honesty, which would be considered as a microethical topic (“K-12 Ethics Education,” n.d.) There is also evidence of possible pushback regarding K12 ethics education, as some high school teachers are forbidden from utilizing their courses to advocate political and/or ideological topics (“K-12 Code of Ethics | Stop K-12 Indoctrination,” 2017).

The Next Generation Science Standards (NGSS) provides comprehensive statements for multiple subjects, which includes both explicit engineering and engineering topics integrated into other areas such as physics, biology, and earth systems. For example, “K-PS2-S Motion and Stability: Forces and Interactions” expects that students are able to analyze data pertaining to scientific and engineering practices (“K-PS2-2 Motion and Stability: Forces and Interactions | Next Generation Science Standards,” n.d.). These standards detail the expected understanding of K12 students regarding education goals and how to meet them. Furthermore, the NGSS includes ethical concepts in its standards (Guzey, 2015). For example, under Appendix H in the

NGSS standards, high school students are expected to understand that "Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions" (*Read "Next Generation Science Standards*, n.d.). The NGSS seeks to prepare the future STEM workforce, and some believe that engineers will be the most needed professionals (Rogers, 2015). In providing targeted concepts to be covered in courses, NGSS also can have engineering topics intersect other subjects, which could lead to engineering concepts being implemented in non-engineering courses (Amos, 2015; Moore, 2013; Glancy, 2014; Moore, 2012; Bottomley, 2013). There are 20 states that have adopted NGSS and 24 states that have developed standards based on the NGSS (Colorado is among the latter group) (NGSS, 2019).

For engineering specifically, Project Lead the Way (PLTW) has been influential in the integration of engineering into K12 education. PLTW, a nonprofit American organization, does not explicitly set engineering standards, however does align with other standards, such as Common Core's Mathematics Standards and the NGSS ("Mathematics Standards | Common Core State Standards Initiative," n.d.). PLTW, develops commonly-implemented STEM curricula and provides funding for K12 education (Virani, 2012; Tims, 2010; Wright, 2010; Pinnell, 2013; Bottomley, 2013; Welty, 2008). The organization initially only focused on high school engineering programs, however now has multiple themes and has extended into K-8 education (PLTW, 2019). PLTW provides educational grants, where schools pay a fixed fee to gain access to all curriculum, course software, and teacher instruction trainings. It should also be noted that PLTW curriculum can be purchased for both public and private schools (PLTW, 2019). For the 2018-2019 school year, PLTW has put an emphasis on ethics and the importance of inclusion in K12 education (PLTW, 2019).

Schools must also adhere to standardized tests such as the SAT and the ACT, which are the leading U.S. college admission tests. However, these tests do not explicitly integrate engineering nor ethical topics. ("Inside the Test," 2015; "The ACT Test for Students," n.d.). Additionally, there is currently no Advanced Placement (AP) engineering course established, nor among International Baccalaureate (IB) programs. However, both programs have partnered with PLTW in order to meet the needs of K12 students ("AP + Project Lead The Way | AP Central – The College Board," 2018; ("Project Lead The Way (PLTW)," n.d.).

Another teaching standard that impacts K12 education is the requirement of teacher licensure. The Colorado Department of Education requires that K12 teachers must have a bachelor's degree (or higher) and have completed an approved teacher preparation program to become certified ("Colorado Teacher Certification and Licensing Guide 2019," 2019). However, these requirements apply to public schools, and private schools do not require necessarily this certification of teachers ("Colorado State Regulations—Office of Non-Public Education (ONPE)," 2019). As elaborated on below, it was also discovered that there is a shortage of STEM-based high school teachers ("U.S. Physics Teacher Shortage and the Need for PhysTEC," n.d.).

2.5 Evidence regarding EESI integration in K12 education

If students are initially introduced to engineering without discussion of EESI, they may develop an idea that it is not important. This general idea has been termed "null" or hidden curriculum (Polmear et al., 2019). Furthermore, engineering may not attract students who want to help people if engineering is viewed solely as “math and science”. Many students are attracted to the notion of helping others, so it is important that engineering is viewed in this capacity (NAE “Changing the Conversation: Messages for Improving Public Understanding of Engineering,” n.d.).

Existing literature on EESI integration in K12 education was reviewed, exploring EESI integration in both courses and co-curricular environments. When searching for ethics-based papers from the American Society for Engineering Education (ASEE) PEER resource, 446 papers with “ethics” in their title were returned, however none of them were in the K12 division (“ASEE PEER - Search Results,” n.d.). When conducting a general search on “ethics”, 7709 papers were returned, with 178 in the K12 / Pre-College division. While this seems like a lot, there was not significant discussion of ethics in the majority of these papers. The few exceptions are described in more detail below (Albright, 2015; Rogers, 2015; Petry et al., 2017; Siverling et al., 2017). For example, Bottomly (2017) created a rubric to example engineer activities in K12 settings that included ethics as a topic area; however, among ten activities examined ethics was only identified in one. Another example is in a Delphi study by Hartman (Hartman & Bell, 2017). After examining papers returned through the ASEE PEER search, only 6 were identified with a title including “macroethics,” and a subsequent search of “societal impacts” in titles returned 12 papers. To summarize, there is not much evidence indicating that ethics in K12 engineering education has been adequately researched.

Additional information on EESI integration was found through determining what educational levels it is most implemented at. As discussed in limitations, there is a notable lack of research regarding EESI integration in K12 education. However, there is some evidence that engineering education at the high school level is incorporating EESI topics through STEM-based learning. For example, a research study was conducted to examine the quality of K12 engineering education, and states how the fifth iteration of the developed framework focused on how “high school science teachers implemented an integrated STEM module representing engineering in their classroom.” (Moore et al., 2014).

EESI is not exclusive to Colorado, and schools throughout the United States have incorporated ethics into STEM curriculum, indicating that ethical topics are important enough to be included. An example of a high school focused on STEM outside of Colorado would be the South Carolina Governor’s School for Science and Mathematics, where pedagogy tools and assessments were developed with regards to the ABET accreditation standards, emphasizing ethics, professionalism, design and process thinking, leadership, project based learning, and public speaking skills (Albright, 2015). In one example, when explaining a biomedical project designed for high school students, ethics were included in the project considerations, where the students were assisted in understanding the ethics involved with research on human and animal subjects. This example sought to prepare them for laboratory work on research that involves such (Rogers, 2015). Furthermore, one of the expected outcomes of this project was “students will understand the ethical issues regarding engineering in human health.” It is notable that, while this is an engineering class, the topics detailed in the project may be considered to branch into other STEM fields, and the importance of ethics is still present (Rogers, 2015). There is also existing research that details multiple approaches to engage students in STEM education through linking authentic engineering practice to the K12 setting (Petry et al., 2017).

EESI may also be integrated in co-curricular activities in the K12 setting. Examples of this integration may through clubs and service learning. Among engineering-based clubs, robotics has strong representation, such as the FIRST Robotics organization (Fletcher & Haag, 2016). Robotics clubs may implement EESI through design, communication, or student training to name a few possible avenues. Service learning may take the form of community projects, and there is evidence that college outreach helps high school students get involved with their community, which may implement EESI considerations (Jones, Trusedell, Oakes, & Cardella, 2016).

TeachEngineering.org, a website providing public K12 engineering modules, was also used to explore evidence regarding EESI integration. After conducting a search for ethics-based modules on the site, only one module detailed EESI integration ("Engineering Ethics: Evaluating Popular Inventions," 2015). This shows further evidence how this research study was driven in part from a lack of existing research regarding EESI integration in K12 settings.

2.6 Lessons from EESI integration in higher education

A recent National Science Foundation (NSF) study explored macroethics education in engineering and computing in higher education (Polmear et al., 2018; Canney, 2017). This K12 study is an off-shoot from that project There were multiple findings from that research that will be cross-compared with this study. First, the higher education study determined that some college faculty were unfamiliar with the idea of macroethics, based on faculty interviews (Polmear et al. 2018). This knowledge was applied to this study by designing the interview to ask teachers distinct questions related to “environmental and societal impacts” and “ethics” separately. Only 30% of the college faculty who responded to the prior research survey believed that undergraduate students in their program had sufficient education on both the societal impacts of technology and ethical issues (Bielefeldt, Polmear, Canney, Swan, & Knight, 2017). This finding was somewhat surprising given that 97% of the survey respondents integrated environmental and/or societal impacts into one or more of their courses (Bielefeldt et al., 2017), and many described this integration in co-curricular activities that they advised and/or mentored (Bielefeldt et al., 2017).

College faculty were able to identify obstacles to ethics implementation in engineering education (Polmear et al., 2018). The information and definitions of these obstacles will be cross-compared with those identified through emergent coding by interviewed teachers in this study to determine if certain obstacles are present at multiple educational levels. These higher education obstacles were revealed through both open-ended survey responses and interviews; both of these approaches allow for respondents to provide answers with greater depth. Following on this, many faculty instructors were concerned with student pushback (Polmear et al., 2018), detailing an obstacle to EESI that will be compared with obstacles that emerge in this study. However, if students were introduced to EESI in a K12 setting, this integration would not be unexpected in postsecondary education. Furthermore, these obstacles were identified through interviews, lending credence to conducting interviews over surveys.

Additionally, multiple types of pedagogy were utilized in implementing ethical topics in postsecondary education (Polmear et al., 2017). Some examples of these different types included having students assess case studies, write some form of reflection, and/or engage in a discussion with their peers. This information led to multi-answer questions in a survey form, however further detailed information was acquired through interviews and classroom observations (Polmear, 2019). The results of this work in higher education informed this research study of K12 settings.

2.7 Colorado case study

It was decided to focus the study on EESI taught within high schools in Colorado. It was thought that the local reputation of the University of Colorado Boulder would entice Colorado-based teachers to participate in the study. Given that this study focused on only teachers in Colorado, state-specific information was researched to provide context. First, after examining the differences between state control on K12 education versus district control, it was identified that the Safety Net Standards, implemented by the Office of Facility Schools, provided state-level regulations that must be met by Colorado schools. These standards detail the most essential concepts and skills for K12 students to master, and it is assumed that each school district adheres to these standards (“Curriculum | CDE,” 2019). Following on this, it was revealed that there are three predominantly represented high school statuses. The first is public schools, which operate under a recognized district and adhere to state-level (and federal) educational standards as well as those defined in the district they represent. Public schools are funded by the government. The next is independent schools, with one notable version being charter schools. Charter schools may be both public or private in nature, however the defining trait is that charter schools receive government funding while possibly operating independently of the state-level standards. A public charter high school may allow for a lottery application process, and/or adheres to some district or state standards. A private charter school acts predominantly independent of established educational standards and may have a more selective application process. Finally, private schools operate independently from state education standards and receive non-governmental funding ("Colorado Non-Public Schools | CDE," 2019).

After further research among existing literature, it was not discovered if ethics education is typically implemented in K12 education, with the exception of academic honesty expectations and the related area of "character education." Ethics education is related, however different, from character education, and character education is further detailed according to the former law "No Child Left Behind" ("No Child Left Behind," n.d.). As is the case with this law, character education has also generated controversy and opposition (Kohn, 1997; Davis, 2003). In Colorado, character education has transformed into 'social and emotional learning', which includes the element of "responsible decision-making" which encompasses ethics. The state-level standards do not place any significant emphasis on ethics education, where the theme of making "ethical and safe choices" is more so focused on behaviors related to mental health (Colorado Department of Education, n.d.). In 2020, new Colorado standards for computer science education in high schools will require "computing solutions can have impacts (personal, ethical, social, economic and cultural) based on their use" (Colorado academic standards, n.d.).

Regarding Colorado high school information, it was determined that there are currently 178 established school districts ("Colorado Education Statistics | CDE," 2019). Some districts, notably those in rural areas, only have one public school in the district;

this possibility was identified and sought to be represented in this study. With information gathered during March of 2019, there were 509 public high schools in Colorado (“Colorado Education Statistics | CDE,” 2019). Another statistic reports 551 public high schools (which may include public charter schools) and 90 private high schools (“Colorado High Schools,” 2015). Regarding this contradiction, the approximate ratio of public to private high schools in Colorado is 6 to 1. Finally, possible shortages of STEM teachers in Colorado high schools were examined. It was determined that, as far back as 2005, there has been a shortage of both mathematics and natural science teachers in the state. With updated information from 2015 to 2018, the shortage of mathematics and natural science teachers were for grades 7-12 indicating that there has been a notable shortage among STEM-based teachers (“Teacher Shortage Areas,” 2018).

2.8 Limitations in literature review regarding any gaps in information

There is a lack of existing research focused on ethics in K12 engineering education. While there is plenty of work detailing the implementation of engineering programs in K12 education, specifically in high schools, very little information was revealed regarding ethical pedagogy in these engineering programs. After expanding the review into public examples of K12 engineering education, such as those found from the TeachEngineering resource, substantial examples of engineering ethics pedagogy were not found. Regarding TeachEngineering, and as mentioned above, only one module concerning engineering ethics was available (“Engineering Ethics: Evaluating Popular Inventions,” 2015). This lack of representation of ethics in K12 engineering education was another driver for this research study.

3. Methods

This section describes the qualitative research approach used in this study. This includes detailing how high school teachers were identified and invited to participate in the study. Following this, details on the preparation regarding conducting teacher interviews is described, which includes how a semi-structured interview format was adapted to address problems identified in the initial interviews. The resulting audio files were transcribed through the software Trint and were further edited to best reflect the accompanying audio file. These transcriptions were first examined according to an initial codebook, which is considered the first iteration of qualitative analysis. This process is detailed below and describes the revisions that were made to create a grouping system (second iteration), and the reasons for why this system required later revisions. The third and final qualitative analysis iteration was represented as a flowchart.

3.1 Development of research questions

The subject of this research study was identified through prior understanding of the implementation of ethical topics in engineering education within higher education. I hypothesized that students with earlier introduction to engineering ethics are likely to develop a stronger foundation for future ethical reasoning. High school students may be exposed to engineering through curriculum and co-curricular activities, and it is of interest to know whether or not this early introduction includes ethical issues. The question regarding if, how, and why high school teachers introduce ethical topics pertaining to engineering was identified as important for this study. Because little has been published on this topic, the process of interviewing teachers, in order to understand their perspectives, was identified as the best research approach. Qualitative research is designed to answer questions with non-numerical answers, such as the "how" and "why" of non-polar questions. Given the lack of previous research on the topic of ethics integration in high school engineering education, it was decided that interviews would be a superior research method over surveys. Semi-structured interviews allowed for follow-up questions personalized to the respective teacher interviewee. This led to a greater depth of information as opposed to a larger number of teachers studied through a survey. As detailed further below, high school students were not directly studied as many are considered minors, which complicates the consent process for conducting research on human subjects. In addition, individual student learning can vary within the same classroom; thus, interviewing teachers allowed their intent to be examined.

3.2 Human subjects research

In order to ethically conduct this human subject research, IRB training was completed through an online course prior to interviews taking place. In the summer of 2017, I became involved with the CU Summer Program for Undergraduate Research (CU SPUR). This research was part of a study funded by the NSF exploring how ethics and societal impact topics are taught to college students. The study included exploring open-ended survey responses from college faculty who integrate engineering ethics into co-curricular activities that they advise and/or mentor. My specific role in the research was to code these faculty responses using a codebook created through an iterative process that included discussion and comparisons with other researchers. In preparing to engage in human subject research, I completed two online CITI Program courses. These courses were *Human Research: Social Behavioral Research Investigators* and

Key Personal and *Responsible Conduct of Research for Undergraduate Students*, both of which were completed in June of 2017.

I continued to be involved with the ethics research study past the duration of the SPUR program, which was my first introduction to qualitative research. While this opportunity allowed me to recognize my interest in qualitative analysis, my thesis was largely motivated from my own experience. When I was in high school, I was involved in a pre-engineering academy that sought to introduce and prepare students for engineering in higher education. In learning about ethics implementation in postsecondary engineering education, I began to think back on what I experienced as a high school student in this program. Recalling an ethics unit in one of my high school engineering courses, I decided to examine high school engineering programs, or non-engineering courses that incorporate some engineering topics, to see how ethics are represented. Initially it was planned to survey, interview, or otherwise engage with high school students directly, however this would involve conducting human subjects research on minors. This type of research requires parental permission, which can be a somewhat challenging process ("Guidance Document: Research in Schools," 2013). In addition, the process for receiving IRB approval to conduct this research is more extensive. Thus, it was ultimately decided to interview high school teachers to understand their perspectives.

Dr. Angela Bielefeldt, my mentor of both the SPUR research and my master's thesis, created and submitted an IRB protocol detailing the actions that would be taken on behalf of this research thesis, including the recruitment materials and consent process. This IRB submission was approved on May 8th, 2019, as an exempt category 2 study with minimal risk. This allowed for the collection of human data through conducting up to 20 interviews with K12 teachers and 20 interviews with college faculty/staff experts in K12 engineering education. The IRB protocol number is 19-0263, and more information can be found in Appendix A.

3.3 Identification of high school teachers and recruitment

After having developed the research questions and the general procedure to examine them, the study began identifying individuals who would provide their perspective on ethics in high school engineering education. These individuals consisted of high school teachers in Colorado and faculty of various universities that are engaged with outreach to high schools. The initial goal of the study was to conduct 20 interviews of high school teachers and 20 interviews of college faculty. However, this goal was adapted as the study was underway due to time constraints and the rate of teacher respondents. Ultimately, it was decided that college faculty perspectives were not essential to the research and this element was eliminated from the scope of work presented in this thesis. Therefore, the focus was on the high school teacher perspectives.

The process of determining which high school teachers to recruit to participate in the study remained consistent throughout the duration of the research and included targeted selection and snowball sampling. The first step utilized the websites of various high schools in Colorado. These schools were identified through a mixture of personal experience and knowledge, recommendations made by college faculty, and later through recommendations made by the interviewees themselves though what is called snowball sampling. A goal was to have at least two public high schools per school district represented, as well as representation of charter and private institutions, both religiously-affiliated and nonsectarian. After identifying a particular school, the online directory of the school was examined to identify a teacher who taught an engineering-based course. If no engineering teacher was found, teachers were examined for any subject matter in the STEM fields, such as but not limited to, mathematics, science (notably life and environmental sciences), computer science, and other technology-based courses. Additionally, if the school website had information regarding clubs, teachers who lead or mentored clubs related to engineering and/or STEM were identified. As teachers were being identified, their contact information was recorded within an Excel document and additional information was collected so as to best organize which individuals would be invited. This information included whether they taught at a public, private, charter, religious, or other type of institution. The school district the institution operated in was recorded for public and charter schools, and the region of Colorado was identified for each school. The identified individuals were organized within spheres of influence, such as the subject they taught, the school they worked at, the district they represented, the region they taught in, and, should the school's website publicly display it, the courses they teach and their academic focus.

After identifying one applicable teacher to invite at the selected institution, further investigation was done to identify at least one other teacher to potentially invite. This was to allow for a broader perspective than just engineering teachers, as teachers engaged in STEM fields may also implement engineering topics in their classes as well as ethical ones. Additionally, contacting multiple individuals at a high school was believed to increase the number of respondents to the email invitation, as it was difficult to predict the response rate of those invited. Regarding the considerations of status, district, and region of these schools, the invitation list was designed to allow for an adequate representation of each identified consideration. The total number of high schools represented by invited teachers was 69 public schools, 14 charter schools, and 9 private schools. The initial number of identified teachers were 82 with the goal of identifying between 60 and 100 teachers given the uncertainty regarding the response rate of those invited. This was later increased both due to snowball sampling and further research regarding teachers at charter and private institutions, to better represented these types of high schools. Ultimately, 94 high school teachers were invited to participate in the study, and more information may be found in Appendix B.

The invitations to participate in the study were emailed out in three waves to selected high school teachers. This strategy enabled adaptation to the response rate, and potential snowball sampling from teachers recommended by interviewees. Interviewees were asked at the end of their interview to provide the names of any teacher that they believed would be important to interview. This question was optional to answer, and anyone recommended was added to a separate contact list to be possibly invited to the study. The first interview invitation was sent out on May 24th inviting 40 high school teachers who taught engineering explicitly or included some notable aspect of engineering in their instruction. The email invite can be found in Appendix C and was sent by Dr. Angela Bielefeldt introducing the research study and myself as the researcher. As an incentive to increase response rate and to compensate for the time of those invited, a $50 Amazon e-gift card was promised upon the completion of the interview. Originally it was planned to begin the interviewing process earlier, however the Institutional Review Board (IRB) had to approve the human research study before any interviews could take place. Given that the invitations were sent out at the end of the traditional academic year (Spring 2019), there was perhaps a lower teacher response rate due to how occupied they were in their teaching. The initial number of responses received was seven; ultimately five interviews were completed among this group.

After the summer elapsed and it was believed teachers might be more available, a second group of teachers were invited to participate in the study. This group was comprised of 7 teachers recommended by the interviewees (snowball sampling) and 42 additional teachers representing primarily non-engineering STEM fields. This second wave of invites was sent on August 7th, 2019, with the intention to have a greater response rate as teachers may be returning from any summer trips and preparing for the school year. Among this second group of STEM-based teachers, 8 responded to the email and ultimately 6 interviews were completed. Among the 7 teachers identified through snowball sampling, 2 responded however only 1 interview was completed.

A final set of five teachers were invited to participate in interviews on September 27th, 2019. It was determined that there was a lack of public charter and private high school representation among the pool of interviewed teachers in comparison to public high schools. These five teachers were identified through teaching at schools of these statuses, and their instruction of either engineering or other STEM based courses. Of these five teachers, 3 responded and 2 interviews were conducted, ultimately leading to 14 total high school teachers interviewed. In all, 94 teachers invited, 19 responded with some level of interest (20% response rate), and 14 interviews completed indicates that

15% of invited teachers participated in the study. This accounted for challenges such as scheduling the teacher interviews and initial respondents being later unable to participate.

3.4 Development of interview materials and procedure

An initial interview script was developed for the high school teacher respondents. This interview script was initially developed by my mentor and underwent edited iterations among myself and other research mentors (Dr. Madeline Polmear, Dr. Daniel Knight). The final script was agreed upon by all who assisted in these iterations, and is shown in Appendix E. The interviews were decided to be semi-structured because of the desire to both have each teacher interviewee respond to the same primary questions, which were consistently asked, while also allowing for appropriate follow-up questions that varied depending on the responses of the interviewee. Structured interviews, on the other hand, would have lacked the ability to follow a particular response, either to gain further understanding of an individual teacher's perspective, or lead to another follow-up question (Pathak & Intratat, 2012). It was decided to interview teachers, rather than request that they complete a survey, because this method allowed the teachers to express their perspective of integrating ethical topics to a greater degree. A survey would have had them indicate their level of agreement for various questions and could ask open-ended "how" or "why" questions, but written responses often lack depth when compared to an interview. Thus, while a survey would have allowed for more teacher respondents to participate in the study, it was determined that there was more insight and value to be gained from a study with greater depth on the teacher perspectives, while having less respondents.

Before scheduling any interviews with the respondents, two pilot interviews were conducted to practice the interviewing process and assess the interviewing script for improvements. This was included as an important step as, prior to this study, I had little experience conducting interviews and sought to conduct the interviews as uniformly as possible for more consistent data collection and analysis. These pilot interviews consisted of one high school teacher and one college faculty, both of whom were identified though connections established prior to this study. The interview process was semi-structured, so the interview script was adapted if the effectiveness of the interviews warranted it. The primary questions were only slightly modified in order to increase teacher interviewee understanding of the question of note, while the follow-up questions changed on an interview-by-interview basis depending on the interviewee's responses to the primary questions. Outside of adjustments to the interview script, I reflected and listened back to completed interviews and took personal notes regarding my effectiveness as an interviewer to use in following interviews.

Two primary interview questions underwent slight revisions depending on the subject focus of the teacher interviewee. If the interviewee primarily taught engineering courses, the question wording was:

"Would you please describe how you have integrated engineering into your teaching?"

"Do you personally believe that K12 engineering programs should integrate ethics and/or societal and environmental impacts?"

If the interviewee primarily taught non-engineering courses, the question wording would vary as shown below.

“Would you please describe how you have integrated engineering **topics** into your teaching?”

“Do you personally believe that K12 **STEM** programs should integrate ethics and/or societal and environmental impacts?”

This decision for revised question wording was made after conducting 2 interviews, one with an engineering teacher and the other with a non-engineering teacher, as it was determined that asking a non-engineering teacher how they taught engineering led to confusion and the assumption that they were being asked about non-existent engineering courses. Both the initial and final interview scripts can be found in Appendix E.

After an identified teacher responded to the email invitation, communication was established to determine a time for each interview. The interviewees were asked for their best available time, and their preferred method of conducting the interview. These interviews were planned to take between 30 and 60 minutes, and should the interview reach the 60-minute mark, I would intercede and inform the interviewee of the time. Some interviews lasted longer than 60 minutes as the interviewee was interested in further giving their perspective and had the time available to do so. The interviews were conducted over Skype or by phone, with the selection of the method falling onto the interviewee’s preference.

After establishing a time, date, and interview method, the IRB research letter of consent was sent no later than 3 days before the interview was to take place. This was to provide the interviewee with enough time to review the letter of consent as well as act as a reminder of the interview, as some interviews were scheduled a month in advance.

Consent was given verbally at the beginning of the interview after confirming that the interviewee had read the letter and was informed about the research study. The IRB letter of consent can be found in Appendix D. After consent was given, the interviewee was asked to provide a pseudonym that their responses would be attributed to. This was designed so that the interviewee may remain anonymous regarding the data that was analyzed and reported in this thesis study but still able to recognize their own contributions should they wish to do so. The research portion of the interview started with primary questions regarding the teacher's pedagogy (questions 2-4). This was followed by asking the teacher about environmental and/or societal impacts integration and personal insights (questions 5-7). Next, questions 8 and 9 detail explicit ethical topics integration, as well as the identification of obstacles. Finally, question 10 allowed for the teacher interviewee to express any concluding thoughts. After each interview was completed, the interviewee was emailed the $50 e-gift card for their participation in the study.

3.5 Transcription process of interviews

Following the completed interviews, the audio file created was uploaded to the transcribing website Trint. A text document was created by the software and detailed a rough outline of the conducted interview, including timestamps. Using the audio portion of the software, the document was manually corrected to better reflect the audio of the interview, which may have been misunderstood due to accents, background noise, variable connection, and conversation overlap. Included in Appendix F is both an initial transcription, showing an example of the rough generation, and an edited transcription.

Transcript revisions were done to correct the proper words used, disregarding the usage of sentence extenders, notable pauses in conversation, and some grammatical mistakes. It was decided to use clean verbatim transcription, which involves the removal of sentence extenders and commonly repeated words, such as “Um”, “Like”, “You know,’’ as opposed to strict verbatim, which includes the fully detailed wording during the interview including pauses and so forth (“True Verbatim versus Clean Verbatim Transcription,” n.d.). Clean verbatim transcription was selected because these words and phrases did not add to the interviewee’s perspective, and their removal presented a more organized transcript. Initially these transcriptions took approximately four times longer than the correlated audio file length to complete. This was largely due to my inexperience in transcription and emphasis on extraneous details at this point in the study, such as grammar. In later interviews, transcription editing took approximately twice as long as the audio file length to complete, focusing more on editing the main ideas of the interview over the grammatical mistakes created by Trint. Parts in the transcriptions identified as being important for analysis were later edited with regards to grammatical, and other, mistakes. The reason for this disregard was to move on quicker to analyzing the main themes and topics present in the transcribed interviews. After the transcribed interviews were qualitatively analyzed, further corrections were done as necessary for notable portions of the text. These further revisions were done for all quotes included in the results of this research study.

3.6 Analysis of transcripts

After most of the interviews with high school teachers were completed and transcribed, a codebook was created to analyze the transcribed text. This codebook was created based on the notable themes discussed in the interviews and allowed for distinctions to be made between the representation of these themes. Initially, this codebook was planned to be the primary method in analyzing the teacher perspectives. These codes would be determined from themes present in the interviews and compared to an example codebook regarding co-curricular ethics implementation in higher education (Bielefeldt et al. 2019). This was decided due to my prior experience in qualitative coding of shorter elements from open-ended survey responses (approximately 10 to 200 words) describing engineering ethics education in co-curricular settings. The major blocks in the codebook, which encompassed the relevant individual codes, were determined to be “Macroethical Topics”, “Microethical Topics”, “Pedagogy”, “Demographics”, “Goals”, “Barriers”, and “Others.” This initial codebook can be found in Appendix G.

A qualitative analysis approach was designed through three iterations. The first iteration was constructing the qualitative codebook from the interviewed teacher transcriptions. These developed codes were to be applied to appropriate transcripts and allow for distinction between the teacher perspectives. After determining that this approach lacked the ability to analyze the transcripts in greater detail, the second iteration was designed. This approach involved the definition of three categories pertaining to ethics and/or environmental and societal integration and had each teacher placed in the category that best represented their perspective. To allow for distinction between teachers in the same category, a scale was designed alongside the categories to detail their placement differences within in cluster. A third and final iteration was designed after finding that this approach, while more appropriate then the codebook, lacked adequate definitions detailing the differences between environmental/societal impacts and ethics, and how the teacher interviewees perceived their inclusion of these topics. This final iteration was a flowchart that led to four defined codes. This flowchart was used for each teacher interviewee and codes assigned depended on how they answered the primary questions regarding environmental and societal impacts and ethics, detailing their personal understanding of ethics and/or environmental and/or societal impacts. Furthermore, each teacher's answer was assessed for whether it agreed with the defined understanding of EESI, which involved comparing the agreement of their personal understanding with this "targeted" understanding. For example, a teacher may have answered "no" to incorporating ethics, however provided follow-up examples that were believed to be valid examples of integrating ethical topics. This iteration drew heavily from the grouping method, as it also incorporated a plot similar to the scale in assessing placement of teachers with regards to the four codes. These codes are detailed below:

A1: The teacher interviewee believes they integrate ethics and/or environmental and societal impacts in their instruction. This personal understanding is aligned with the targeted understanding.

A2: The teacher interviewee believes they integrate ethics and/or environmental and societal impacts in their instruction. This personal understanding is not aligned with the targeted understanding (for example, that societal impacts are part of engineering ethics).

B1: The teacher interviewee does not believe they integrate ethics or environmental and societal impacts in their instruction. This personal understanding is aligned with the targeted understanding.

B2: The teacher interviewee does not believe they integrate ethics or environmental and societal impacts in their instruction. This personal understanding is not aligned with the targeted understanding.

Identifying that “Goals” and “Barriers” are two of the most important considerations for the research study, these themes were redefined as categories comprising the teacher perspectives as an additional part of the third iteration. Additionally, the theme of “Importance” was added, which details how important the interviewee considers the implementation of EESI topics. The teacher interviewee perspectives were assessed regarding the obstacles facing EESI implementation in K12 engineering/STEM education and how to address these obstacles. The emergent obstacles identified by teachers were divided into two subcategories, challenges and barriers, for each interviewee that perceived the obstacle. For the purpose of analysis, challenges were defined as obstacles impeding ethical implementation, however could be either overcome or justified. Barriers were defined as obstacles impeding ethical implementation that are currently are impassable. These categorizations are further detailed in the results section of this thesis.

For both the second and final iterations, inter-rater reliability was utilized to ensure accurate interpretation of the interviewed teacher perspectives regarding the categories and codes applied. This was to help ensure the validity of the results in this qualitative research study, where my initial placement of each teacher was compared with my advisor’s placement to highlight examples of disagreement. These examples were discussed and ultimately a compromise was reached that best reflected each teacher’s placement. It should be noted that the second iteration resulted in some disagreements not being resolved and was another reason for the creation of the flowchart. The first two iterations may be found in Appendix G and Appendix H respectively, while the qualitative flowchart may be found in the results section as Figure 6.

3.7 Limitations to research study

There were multiple limitations to this qualitative research study. I will examine each limitation, why I believe it is important to consider, and how it was addressed. First, I had little prior experience conducting interviews. For the earlier interviews some follow-up questions were asked in a way that lacked clarity. Mannerism and comfort of the interviewer (me) may have affected the teacher interviewee responses. As I grew more comfortable in interviewing the invited teachers, these interviews typically were of a higher quality than the former, through personal refinement of the interviewing process. To account for this disparity, two pilot interviews were conducted with individuals I already knew to prepare myself for interviewing teacher respondents. I found that my ability to conduct interviews reached a level of effectiveness I was satisfied with after conducting four interviews. Thus, it would have been more appropriate to have at least four pilot interviews, however the scope and timing of the study did not allow for much variation, and this consideration can only be applied to future work.

Another limitation was that the interview script was changed slightly over the course of the study. As mentioned above, it was determined that a change in wording for some of the primary questions was more appropriate for the teachers of non-engineering courses. However, it is unknown what this changed in their response if compared to the response given from an engineering teacher, with earlier interviewees asked the original primary questions. Another revision not mentioned above but changed for similar reasons regarding confusion on the part of the interviewee, was the changing of “social” to “societal” wording in the interview primary questions script. This change occurred after 4 interviews after finding evidence of uncertainty regarding social impacts.

Another limitation of this study was the timeframe. The master’s thesis was planned to be completed by the end of November, with the defense occurring during the third week of the month. This timeframe limited the number of interviews that could be completed, given the variable response rate to invitations, and limited the scope of analysis regarding the study. Future work is discussed in the final chapter of the thesis regarding work that was not completed in this study but could be followed up on from the interview transcripts, such as analysis on teacher pedagogy differences with regards to EESI implementation.

A limitation of incorrect transcription was identified early on in the study. Due to a range of complications, such as background noise, voice overlap, and poor connection, the generated audio file sometimes lacked understandable discourse for parts of the interview. While Trint was largely able to reconstruct the file, and generated text could be further edited, some portions were unintelligible and were subsequently removed. To address this, measures were taken to have a stable connection, limit external audio, and recognize the problem of voice overlap, however given the two-way nature of the interviews it was challenging to address these problems on the technical side of the interviewees.

A limitation regarding bias was identified in that each of the teacher interviewees knew this study to be focusing on ethics in engineering education. The teachers who respond to the email invite may be somewhat skewed from the overall norm as they may have some ethical background, philosophy, and/or interest that resulted in their response to the email regarding participating in the research study. Leverage salience theory states that if a teacher believed that ethics are not important and/or not implemented in their teaching, they are less likely to respond to an invitation to participate in a corresponding study (Groves et al., 2006; Groves & Peytcheva, 2008).This is important to recognize, despite the fact that this limitation was known from the beginning of the research study. As mentioned above, in meeting IRB regulations in conducting human research, explanation is required that details why the research is being conducted. Any lack of transparency regarding actions to be taken during the study would have human subject research implications.

Another limitation to this research is the usage of subject generalization. To begin, there was generalization regarding the STEM field best represented by teacher interviewees. As explained above, teachers were assigned a generalized focus depending on the courses they teach. However, some teachers instructed courses in multiple fields, leading to some uncertainty on what subject they should be represented as. For example, a teacher of both a biology class and an engineering class could be considered to focus on either science or engineering for the purpose of this study. Ultimately, teachers were assigned these generalized representations according to the subject they seemingly best represented (through teaching AP level courses, number of courses taught, prior background, etc.), although there is the awareness that these generalizations lack properly displaying the identities of teachers of multiple STEM courses.

Following on this, another limitation regarding generalization is that this study only interviewed teachers in Colorado across 7 different school districts. Additionally, 1 public charter network and 2 private institutions were represented through interviewed teachers. It is unknown if a level of saturation was met regarding the representation of different STEM educators. As shown in the results, there was only one (generalized) teacher representing computer science and mathematics. This is due to the response rate of invited teachers, as more teachers representing these fields were invited to the study. Among the teachers invited to participate in the study, 7 were computer science teachers and 2 were mathematics teachers. Regarding the process of generalizing the subject teachers taught, there may have been more teachers invited that teach computer science or mathematics to some degree. However, these teachers were classified either as engineering or science teachers after determining the subject they best represented. Additionally, other subjects, such as physics, were underrepresented among the interviewed teachers. This was partially due to the decision to generalize engineering physics into engineering; with what information was publicly available, 11 invited teachers primarily taught physics courses. Regardless, while it is important that these fields of STEM are included in the study, they are not well represented in comparison to engineering and science. As explained in possible future work under conclusions, it would be important to have better representation of EESI implementation in computer science and mathematics K12 education.

Despite this array of limitations in the research, the study provides new insights into how some high school teachers in Colorado have integrated EESI into their teaching practices.

4. Results

4.1 Interviewee characteristics

The data that comprises this study resulted from 14 interviews with Colorado high school teachers representing engineering or another STEM subject. These teachers came from a total of 13 schools. The characteristics of these schools are summarized in Table 1 below. The schools were assigned a letter to preserve anonymity. The school's status (public, public charter, nonsectarian private, or religious private), the district or organization it operates under (as public charter schools do not work within a district), the Free and Reduced Lunch eligibility among students for the 2018-2019 school year, and the overall graduation rate for the 2017-2018 school year are reported. The districts in which the schools are encompassed by were assigned a lowercase reference letter. While public charter schools do not necessarily operate under the rules of a particular district, they were each assigned a specific reference letter given that they follow established Colorado teaching standards and operate in a K12 network. Additionally, private institutions were given a letter denoted with an asterisk, which indicates the school district whose geographic borders contain the high school. This led to assigning 8 lowercase reference letters to each district or organization represented by interviewed teachers.

Table 1. Demographic data of schools represented by teachers interviewed.

Schools	Classification	District or Organization	Interviewee(s)	FRL (2018-2019)[1], %	Overall Graduation Rate for 4 years HS (2017-2018)[2], %
A	Public	d	Michael	35	89.5
B	Public	e	Paul	13	92.8
C	Public	a	Larry	17	94.5
D	Public	c	David	29	91.6
E	Public	g	Allison	67	82.0
F	Public	e	Joelle	4	98.6
G	Public	d	Olivia	45	87.3
H	Public	f	Simon	13	94.1
I	Public Charter	b	Palden	86	No graduating class
J	Public Charter	b	Ron	57	No graduating class
K	Public Charter	b	Jeff	48	84.4
L	Private, Nonsectarian	h*	Jimmy	NA	NA
M	Private, Religious	f*	Lori, Renae	NA	NA

1: ("Colorado Department of Education: Graduation Rates 2017 | CDE," 2017) Information has rounded up to preserve anonymity.

2: ("Colorado Department of Education: Pupil Membership | CDE," 2018) Information has been rounded up to preserve anonymity.

* similar geographic location, although not within public district

NA = not available; data for private schools not found

As shown in Table 1 and Figure 1, there was a wide range of student economic statuses at the represented schools, as indicated by the percentage of the students eligible for Free and Reduced Lunch (FRL). In addition, graduation rates at the high schools varied and were used as an approximate indicator for student success. There appears to be a relationship whereby high school graduation rates are lower at high schools with a higher percentage of students eligible for FRL. This relationship is not unexpected and has been previously documented ("Building a Grad Nation Report," 2014).

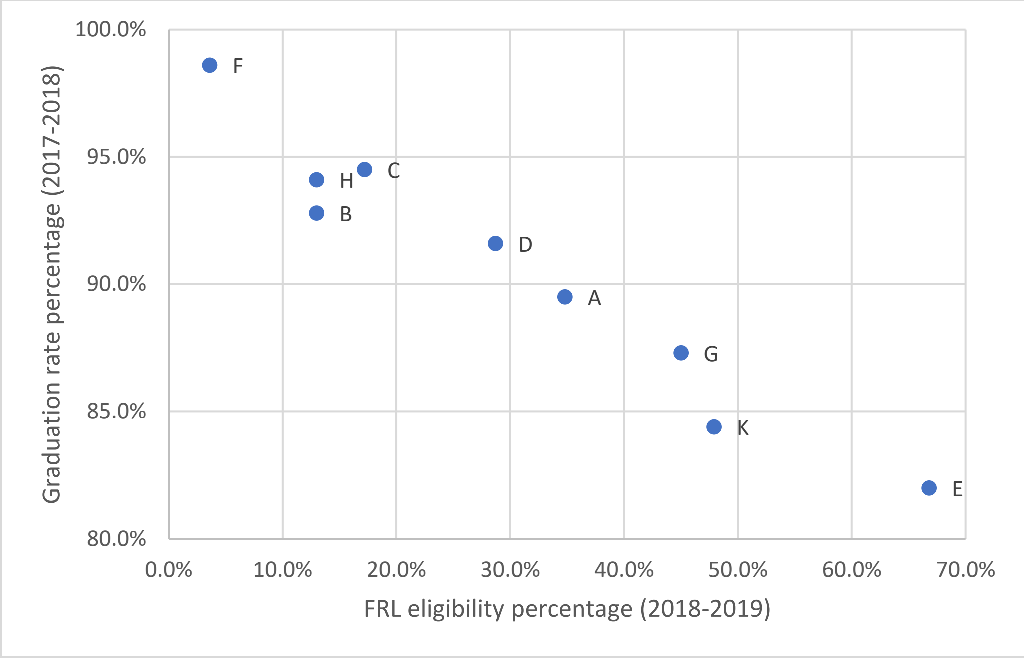

Figure 1. Free and Reduced Lunch eligibility versus graduation rate.

Figures detailing FRL eligibility ranges and graduation ranges have been included for the public and public charter schools represented in the study. It should be noted that some of the public charter schools have not yet had a graduating class (due to the young age of the school) and were therefore omitted from the graduation rates figure (“Colorado Department of Education: Graduation Rates 2017 | CDE,” 2017; “Colorado Department of Education: Pupil Membership | CDE,” 2018).

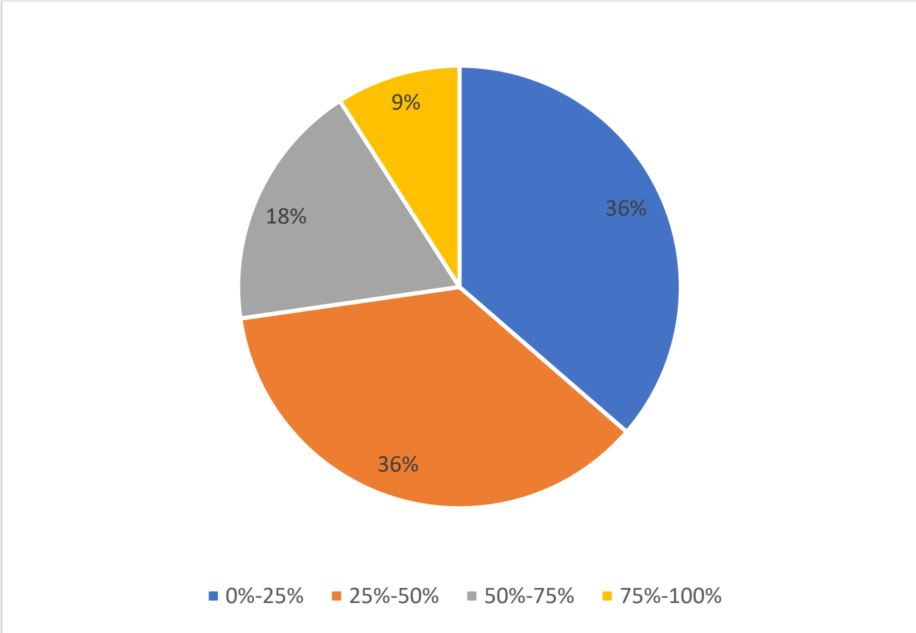

Figure 2. Free and Reduced Lunch eligibility among schools in the study for 2018-2019.

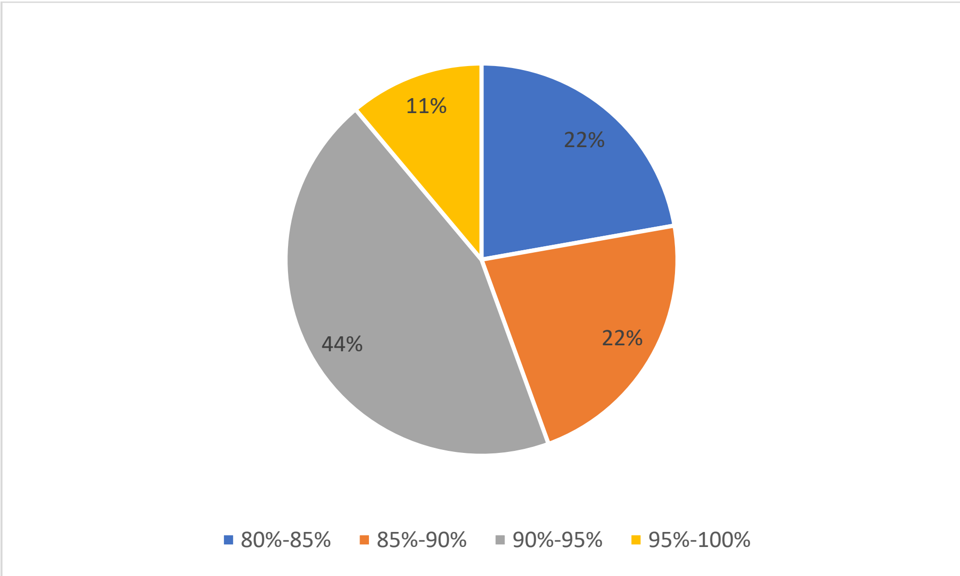

Figure 3. Graduation rates of schools represented in study for 2017-2018.

The teacher interviewees, under their selected pseudonym, were grouped according to their generalized academic subject and any extracurricular involvement if appropriate. Figure 4 below expresses these groupings.

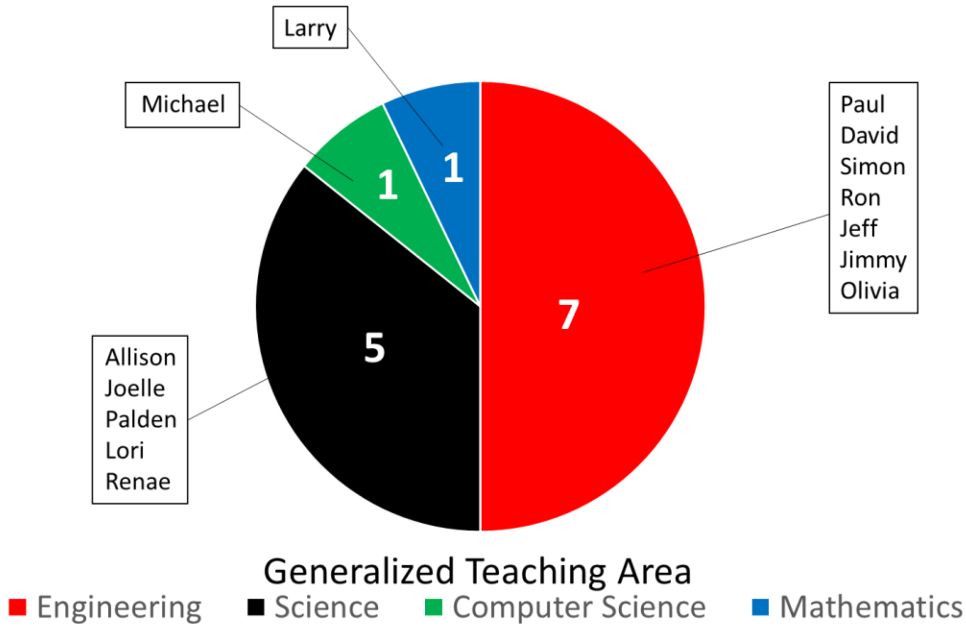

Figure 4. Generalized STEM subjects represented by the teachers.

To note, there were generalization liberties taken in this grouping process to better group interviewees with regards to engineering and non-engineering. For example, the teachers focusing of engineering physics were generalized into engineering. Figure 5 details the respective breakdown of the science group, as it was determined that this generalization represented the largest variation in courses taught by interviewees. Note that the “Broad” term indicates that the teacher interviewee taught numerous science-based courses, and it was unclear which subject was most represented.

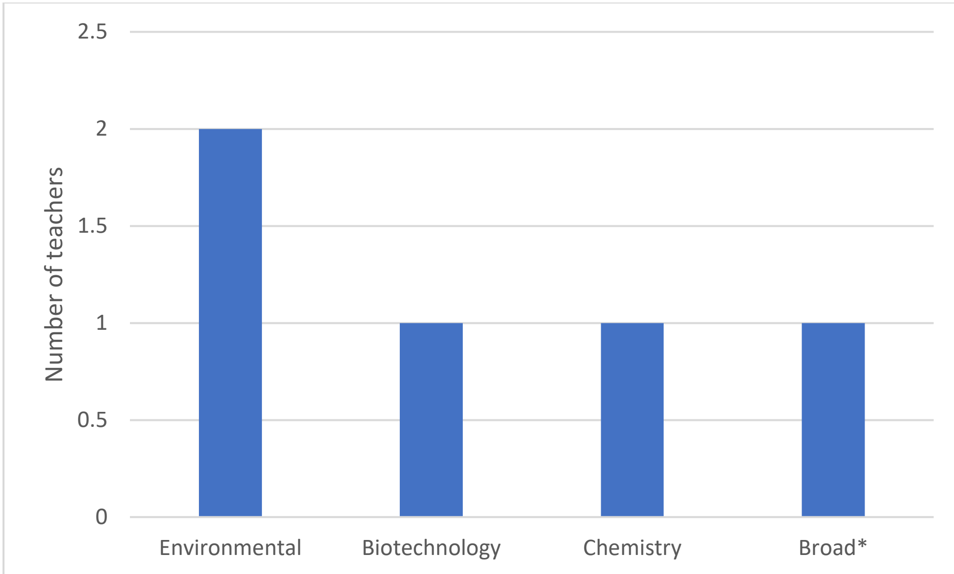

Figure 5. Primary science subjects taught among the teachers.

Table 2. Experience and contextual information of interviewed teachers.

Teacher Interviewee	Years teaching	Years at current school	Degrees	Years in engineering industry	Generalized Subject
Michael[T]	15	3	M.S. Computer Science	18	Computer Science
Paul[I,W]	15	2	B.S. Civil Engineering; M.E. Energy Engineering; M.Ed. Mathematics	10	Engineering
Larry[T]	25	15	B.S. Mathematics Education	0	Mathematics
David[W,T]	15	9	B.S. Physics Education; M.S. Technology Education	0	Engineering
Allison[T]	20	13	B.S. Sport Science; M.S. Sport Science	0	Science
Joelle[W,T]	20	15	B.S. Biology; M.S. Education	0	Science
Olivia[T]	15	10	B.S. Biomedical Engineering; M.S. Biology	0	Engineering
Simon[T]	6	6	PhD Physics	0	Engineering
Palden[W,T]	10	5	B.S. Physics; M.AT. Science; M.S. Atmospeheric Science	0	Science
Ron[W,T]	8	3	B.A. Physics; M.S. Education	0	Engineering
Jeff[T]	6	2	B.S. Civil Engineering	10	Engineering
Jimmy[T]	23	7	B.S. Engineering; M.A. Science Education; M.A. Education	5	Engineering
Lori[I,W]	3	3	B.S. Chemical Engineering; PhD Chemical Engineering	5	Science
Renae[W]	5	5	B.S. Biology; M.S.Science Education	0	Science

T = information was supplied by teacher in a follow-up email to their interview.

I = information was supplied in interview.

W =information was obtained through school websites or another online source (LinkedIn).

4.2 Results overview

The results of this study, as they pertain to the four research questions previously defined, are presented below. As per the nature of the interviews being conducted in a semi-structured manner, there were separate questions asking the interviewees about their personal implementation of environmental/societal impacts and/or ethics. This was to allow the interviewee to express any perceptions on the two subjects separately, whether they view the two concepts as identical, congruent, or entirely removed from the other. Note that both these topics fall under the definition of EESI. While the interview script allowed for interviewee-dependent follow-up questions, the ten primary questions were asked or addressed in each interview. These ten questions may be found in the revised interview script included in Appendix E. Some interviewees answered a forthcoming primary question unknowingly before it was asked, and to avoid repetition, the question was not asked verbatim later during that interview.

4.3 Research question 1: Environmental and societal impacts

RQ1: Do high school teachers engaged with engineering/STEM incorporate engineering environmental and societal impacts in their teaching, and if so, how?

After the teachers were comfortable in the interview and had discussed their general teaching practices related to engineering or STEM, they were asked: “Do you include the societal and environmental impacts of technology in your instruction?” This question was posed anywhere from 15 minutes to 30 minutes into the interviews. Responses ranged from an affirmative response, “yes,” from 10 teachers, to a negative response, “no,” from 4 teachers. Note that 3 teachers had already described their EESI integration in their earlier description of teaching engineering and/or other STEM courses. In addition, 3 teachers who said “no” went on to describe ways that they did in fact integrate EESI, possibly unknowingly. In addition, some noted that only environmental or societal (or social issues) were included. For example, Michael stated that he included societal impacts but not environmental. Other teachers stated that they did not incorporate EESI in all courses they teach, such as Palden who incorporates ethics in her environmental courses, but not necessarily in her engineering courses.

An example response to this question from a teacher who strongly integrated environmental/societal impacts is shown below:

> I would definitely say [environmental and societal impacts] is on the forefront of my mind, and in the past when I have developed projects for students that has been a key motivator. We had one group that tried to make a solar powered car, so I think the societal/ environmental impacts have always been a driving but underlying force in pretty much all of the big projects that I've done. It's hard to find hope these days in the world at large, but I definitely have hope in my students. I truly believe that this is the generation that is going to make the world a better place because they believe it. They want to learn more about how their actions affect the world around them. They care about the environment even if they've never been out there because they have an underlying sense of duty and responsibility to the world. I definitely think that for our students, the kinds of projects that have societal and environmental considerations at their center really resonates with them. *Ron, engineering teacher*

Ron, an engineering teacher, discussed not only how they integrate EESI into their instruction, but also how it aligns with their goal as a teacher. Furthermore, his perspective regarding his students is an example of how students are impacted by this instruction.

Another example from a science teacher who integrates environmental/societal impacts is shown below:

> That's something I think goes back to our [religious] background, that's a huge piece of everything we do. We have really tried, especially in the past five years as a science department, to make sure that everything we're teaching is rooted in something that makes it more meaningful and it gives it more real-life context, and it gives the student more opportunity to feel connected to material. Yeah, we've done all sorts of projects regarding social and environmental impact. And yeah that's something that's really important to us as a department. And it does come back to some of the NGSS, and I think it's also tied in because of our [religious] identity too. *Renae, science teacher*

This quote comes from Renae, who teaches at religiously-affiliated institution, and it is detailed how this identity is tied to the EESI implemented within the science department, alongside the Next Generation Science Standards. Moreover, Renae speaks about her department as a whole, indicating that this EESI is not treated as an individual responsibility of the teachers, rather is implemented on a departmental level.

In contrast, another teacher discussed limited integration of environmental/societal impacts:

> There is one particular area that's in the design and manufacture class [I teach] where we looked at what I would say societal impacts of technology and of automation. And it's one thing that we take a little bit of time with them, and I give the students a chance to have some peer-on-peer discussions on the societal impact of automation. But that particular topic in that class is sort of limited to that

> one unit. I think in the biotech engineering class we focus on societal aspects of bioethics and we talk about that throughout the course, actually throughout the year. The ethics piece is actually kind of front and center because it's played such a big role in biotechnical, biological, medical engineering, those kinds of things. *David, engineering teacher*

It should be noted that David started talking about ethics prior to the specific question on that in the interview. This likely indicates that engineering's environmental/societal impacts and ethics are congruent for David. However, this assumption may be biased as David knew this study to be about engineering ethics based on the invitation email and consent process prior to the start of the interview.

Another example response from a non-engineering educator with limited integrated of environmental/societal impacts is described below:

> I guess I don't explicitly talk about that. But I do talk in my chemistry class about the untapped power of the nucleus and the opportunity for impacting how humans generate energy for our lives. Every first day of school I tell [my students] of the enormous opportunity they have if they can understand chemistry and apply it in the world. … They are going to have an enormous opportunity to affect positive change on a lot of fronts, but obviously the energy and climate connection is where chemistry can have a huge impact. And so, I always try and inspire them about a little bit about how the problems we have today are going to be solved by their generation. That is the Jesuit mentality, where education is not good on its own to be left alone. It's intended purpose is

> to serve others. So, when we are solving problems we are contributing to the greater good. *Lori, science (chemistry) teacher*

Note that Lori also references the broader teaching goals of the school in her response, and how EESI integration is aligned with these goals. Furthermore, like Renae, she links the inclusion of ethics to that of the school's mission statement.

Another science teacher contrasted the extent of environmental/societal impacts integrated among the various courses that she taught:

> I do. I do more in environmental [class] than in geology, but Earth Science has been kind of hit-or-miss just because the kids that we teach are freshmen. Yeah, there is definitely a huge issue of how that is impacting them on a daily basis. In AP Environmental Science, we cover the whole Industrial Revolution. How it changed the earth, and ultimately we hope that what saves us is our technology. Even though it has put us in this pickle, including overuse of resources and unsustainable population growth. In my AP class, they absolutely understand [the societal and environmental impacts]. My environmental class is more ubiquitous. When they are learning how to problem solve, I don't know that they are extending their thinking past what they are doing at that moment. I don't think they are sending their vision past that. *Allison, science (environmental) teacher*

Note that Allison provides an example of incorporating EESI into her environmental science classes, however comments on the distinction between her AP and non-AP variants. So, while she does integrate ethics in her courses, her level of integration is dependent on the type of course and may be further dependent on rigor.

A perspective from a computer science teacher regarding their integration of environmental/societal impacts in their instruction is:

> Our feeder schools and their teachers have done a fantastic job of helping kids recognize digital citizenship and the ideas behind technology as far as the responsibility behind it and the ethical aspects of it. I spend time reinforcing and reminding them of this. And if you are in my AP Computer Science class, that’s part of my curriculum, where we very specifically talk about the ethical aspects of technology. …. A lot of it is just recognizing how the technology we are talking about affects society. Now when you say environmental, that’s a little bit trickier. I don’t see much of my curriculum addressing the ecological aspect of things.
>
> *Michael, computer science teacher*

In this example, Michael details both the understanding his students have regarding societal impacts before taking his class, and how he organizes his curriculum to accommodate this and build upon what they are expected to know. However, he does not have any notable examples of the “environmental” part of EESI.

An engineering teacher who answered that they do not integrate environmental/societal impacts in their classes is shown:

> You know, not a lot. There is something in everything you touch on as the course gets going. For example, I have an article on the most recent issue of [construction] magazine, which is really interesting as it talks about the concrete and steel industry and how mass timber is a kind of a saving grace for both the environment and the construction industry. So that’ll be part of a discussion on the depth of knowledge required to make family conscious economically viable or

> sustainable decisions. But I think those sorts of things are part of a conversation, or ongoing conversation, around each individual project choice. *Jimmy, engineering teacher*

This quote is interesting as Jimmy initially responds “no” to incorporating environmental/societal impacts in his courses. However, he then provides an example of what integration he does incorporate. What can be identified is that Jimmy considers these topics to be best incorporated regarding projects, rather than being an established part of the course curriculum.

Another example of an engineering teacher who does not believe he integrates environmental/societal impacts is shown below:

> No, I don’t really. That’s something I have considered. So right now, for example, I don’t cover much discussion on renewable energy sources as you say the societal impact of engineering. And this is partly because it still remains to a large degree a fairly theoretical physics class with labs that apply that theory... We don’t stray too far from that kind of core curriculum at this point. *Simon, engineering teacher*

This example details how, despite not currently implementing environmental/societal impacts, Simon has considered doing such. It is important to note that Simon teaches engineering physics, which was generalized into engineering in this study. His detail of how the theoretical nature is part of the reason for this non-inclusion indicates a possible obstacle for EESI.

These examples detail the range of responses to the question about the implementation of environmental and societal impacts in their teaching. Overall, teachers are not opposed to including or addressing these concepts, however some may not view what they teach to involve or relate to EESI. There is also variability in how environmental/societal impacts is related to ethics. Before the specific interview question about ethics, it is evident that the teacher interviewees varied on whether they viewed environmental/societal impacts as being linked to ethics. Some teachers explicitly mentioned ethics or ethical topics without prompting while others did not include any mention of ethics.

4.4 Research question 2: Teaching ethics

RQ2: Do high school teachers engaged with engineering/STEM incorporate ethics in their teaching, and if so, how? Furthermore, how do they define ethics with regards to EESI or any other factor?

Research question 2 asked if and how teachers integrate ethics into their instruction. Some teachers clearly viewed environmental/societal impacts as congruent with ethical issues, as noted above and observed in their responses to RQ1. This aligns with the macroethics portion of engineering ethics. However, some teachers may have viewed ethics as distinct from environmental/societal impacts. The explicit question that was asked in each semi-structured interview was: “Do you explicitly integrate ethical issues into the classes you teach?” (If appropriate, the question also included the phrase “and/or the programs you mentor”). This question was asked after allowing the teacher interviewee to elaborate on their environmental/societal impacts integration answer and possibly detail its importance, typically about 25 to 40 minutes into the interview. For reference, the primary interview question regarding environmental/societal impacts integration was question #5, while the question regarding explicitly ethics integration was question #8.

In response to the question of ethics integration, there were 9 teachers that said either "yes" and 5 teachers that said "no". There were 2 examples of teachers responding "no" after responding "yes" to integrating environmental/societal issues. Furthermore, there was one example where a teacher responded "yes" to integrating ethics after answering "no" to integrating environmental/societal impacts integration.

Below is an example of an engineering teacher's response stating explicit integration of ethical issues:

> Well I would say yes I do with the biotech class. Yes, there is an ethics component into every engineering class that I teach. It's spread throughout the entire year in biotech engineering, it's in every single unit. In biotech, we talk about health. We get into genetics, how we are getting to the point where we can test whether someone has a particular disease... But there are ethics involved in everything. When you are talking about cleaning up environmental disasters there is some impact as a result of using microbes in the procedure, and you can have ethical discussions centered around that. *David, engineering teacher*

Something important to note here is that David provides ethical examples pertaining to each of the engineering courses he teaches, showing that his implementation of ethical topics is adapted between classes to be best represented within the context of the course. He also displays an understanding of EESI when he states that ethics has a part in everything he teaches.

The following quote provides another example of a teacher answering the question regarding ethics integration:

> Yeah, in my [course], myself and my partner on the senior team try to find interesting STEM-based articles that have the potential for a controversial topic. We print those articles for students to annotate through additional research. And at some point, maybe a week later, we have a seminar together as a class and say, “All right, what are the issues in the article? What do we want this seminar to focus on? What is the Side A and Side B of these articles?” Once we have clearly defined what those are, students are assigned to A and B. Now that they are on teams, they have a couple of days to design what their argumentative approach. We have also had some genetic engineering concepts discussed. We did one [discussion] that really got students fired up a couple years ago about NASA funding, whether it should be funded publicly or privately. So, anything that gets kids to consider real world science, and think about what the implications are, [is covered]. *Larry, mathematics teacher*

In this quote, Larry discusses how his focus on integrating ethical issues comes through discussions among students. And while he determines the groups in each discussion, a large part of the ethical development experienced by the students is initiated by themselves through their research of the issue. Most of all, Larry focuses on his students to have an authentic experience regarding science, in which ethics plays an important part.

The next quote comes from a teacher who at first stated that they did not explicitly integrate ethical issues into their instruction, however then provided possible examples of integration:

> Explicitly, no. [In discussing] the Kansas City Hyatt Disaster, we talked about ethics in the way that we tried to analyze the root cause of what happened and how there is serious ethical failures there. [After thinking] We discussed the ethics, I guess so, but it wasn't my main objective, sort of a byproduct of what I was doing. We also talked yesterday about building codes and what each code is and why it's important. So, we talk about things like that. It's not my primary driver. *Jeff, engineering teacher*

While the initial response was "no" to integrating ethics, Jeff elaborated about a disaster that has ethical implications. This integrates ethics but his statement indicates ethics isn't his primary focus, possibly indicating a disconnection regarding what EESI encompasses.

Another example quote coming from a teacher who does not believe themselves to explicitly integrate ethics:

> I do not. I try to make sure that everything [students] come across on a regular basis in the materials is ethical, but I don't actually address issues of ethics explicitly. The focus is on the academic work. And we have a pretty full curriculum and it's often quite difficult to get through what we have. And so, I feel that's really the most important thing to address in the course. I think there are definitely situations in engineering where you do have to consider the ethics or

> the impact of your engineering project. We really don't get to that point very often in the engineering physics class. *Simon, engineering teacher*

This quote details a teacher perspective who explains why they do not incorporate ethics. As detailed further below, curriculum time is one of the identified obstacles to ethics integration. And in the case of Simon, the curriculum in his engineering physics course does not currently allow the explicit inclusion of ethical topics for concern that other topics would have to be removed.

As is shown, the teacher interviewees not only had varying answers to the question regarding ethical implementation, but also varied in how they viewed the concepts of ethics. Some examples of different perspectives on "ethics" among the interviews (but not shown by example quotes above) include: academic integrity of students, role and responsibility of engineers/STEM workers, ethics considered integral to curriculum but not necessarily expressed outside of it, and seminars or discussions regarding case studies or current events.

4.5 Synthesis of RQ1 and RQ2

Engineering environmental and societal impacts can be viewed as key elements of engineering ethics in alignment with ABET Criterion 3 Student Outcome 4 (ABET, 2019) and through their inclusion within engineering codes of ethics. For the purpose of analysis, these terms will be defined as being congruent to each other. With that in mind, the method of qualitative coding underwent three iterations before arriving on a system that adequately assesses the teacher interviewee perspectives regarding environmental/societal impacts of engineering and/or ethics integration. This system was a flowchart (see Figure 6) that allowed for one of four codes to be assigned to each teacher depending on how they answered the two primary interview questions regarding integrating environmental/societal issues and/or ethics in their teaching (questions 5 and 8, respectively) and how their personal understanding matches to the understanding that these concepts are congruent. The personal understanding details how the teacher interviewee views their inclusion of these topics, such as giving a negative response to either primary question. However, some teachers seemingly contradicted their initial answer, indicating that their understanding of environmental/societal impacts and/or engineering ethics differs somewhat from the research paradigm. An example would be an interviewee answering “no” to implementing ethics before detailing an example activity that the research identifies as being based on ethics. This possible contradiction posed challenges and was the primary reason that there were iterations in the coding method.

The final categorization methodology using the flowchart explicitly acknowledges these discrepancies, providing a more accurate reflection of the teacher perspectives. The flowchart is shown below in Figure 6. Categorization of A versus B reflects the researcher’s perspective that they do or do not integrate some aspect EESI, respectively. The categorization of 1 or 2 reflects whether the teacher’s understanding of EESI aligns with the paradigm that environmental/societal impacts are a form of engineering ethics (1= alignment; 2 = difference). In addition, following on the scale categorization from the second iteration, Figure 7 shows a plot with an approximate placement of each teacher interviewee, recognizing that within the same code category two teachers may differ in magnitude with regards to the extent of EESI integration in their teaching (A and B) or EESI definition alignment (1 and 2 codes).

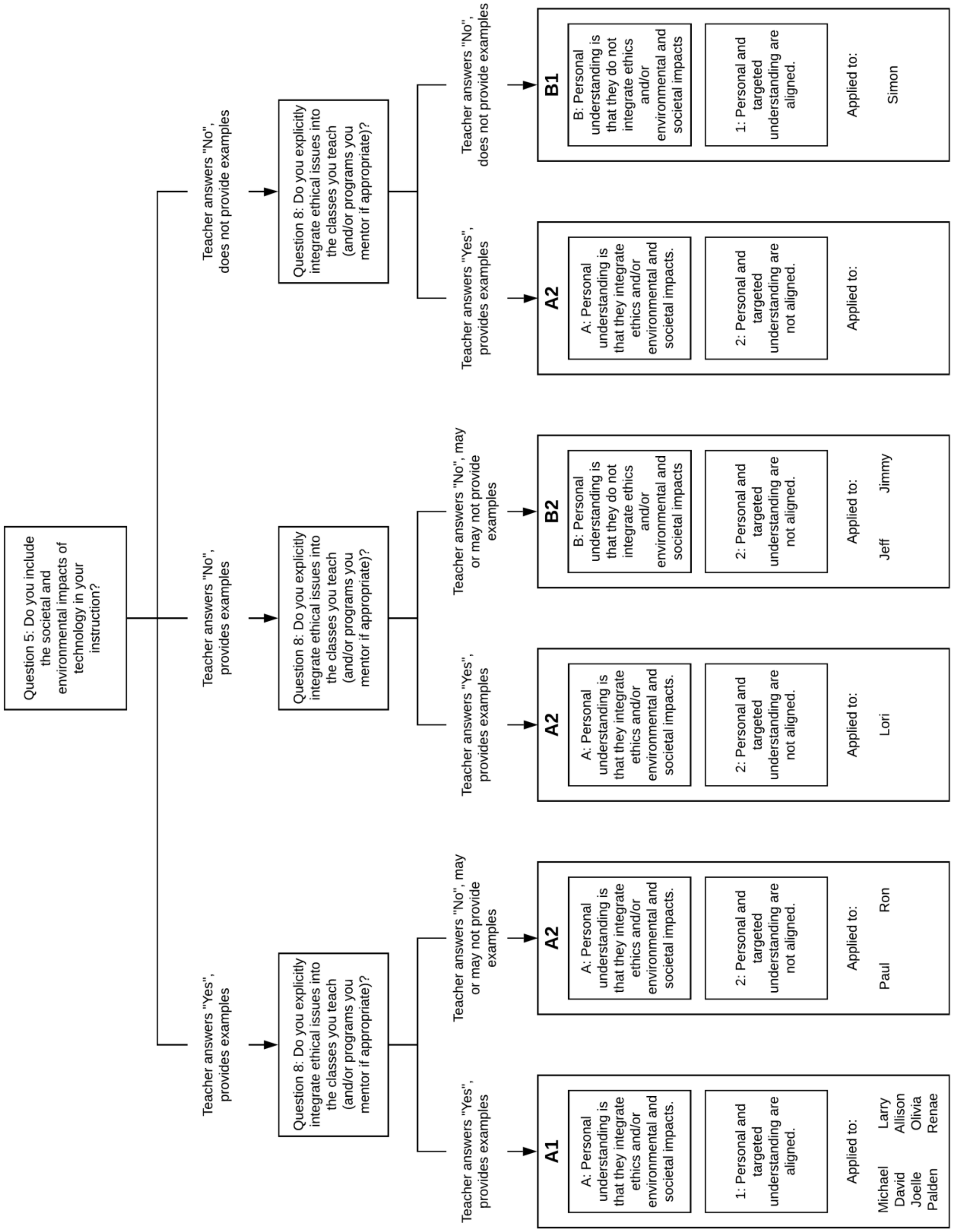

Figure 6. Qualitative flowchart used to characterize teacher's EESI instruction.

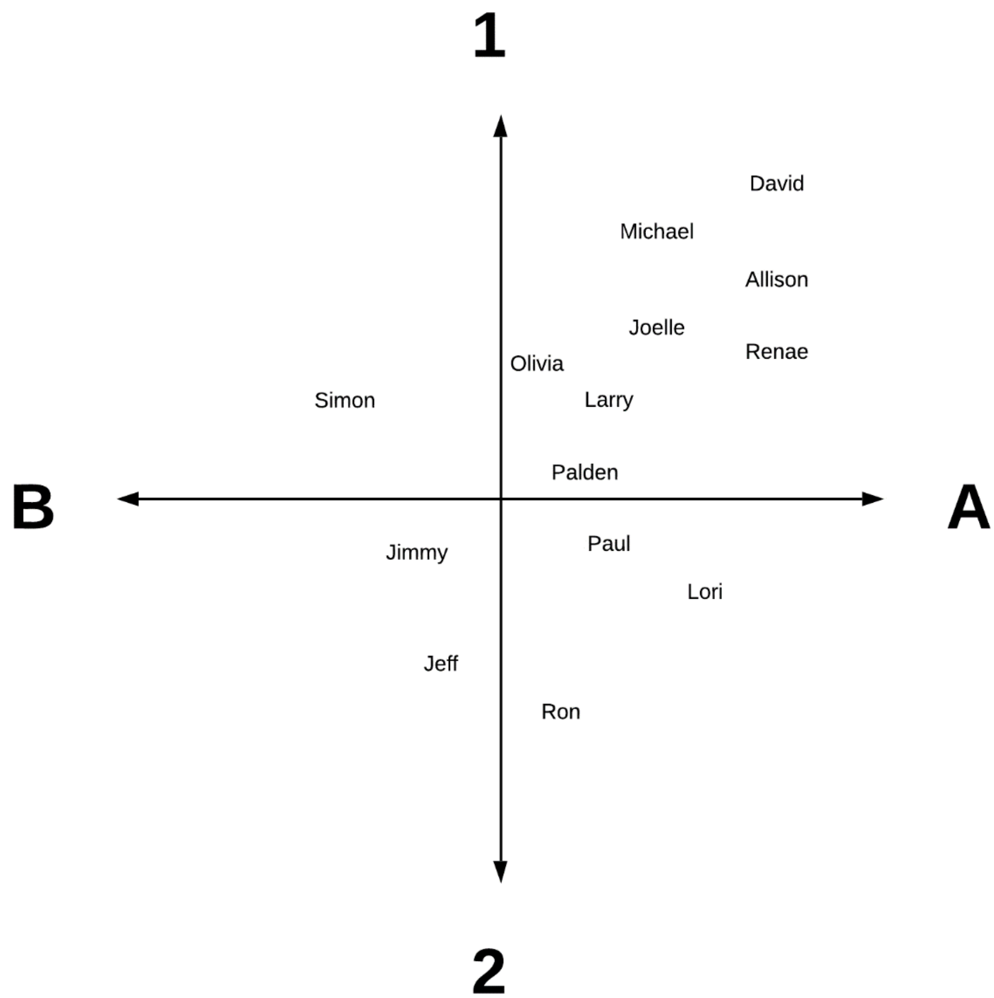

Figure 7. Approximate extent of EESI instruction and definition alignment.

Note that an inter-rater reliability process was used to verify the teacher categorizations. After initial placements, I compared mine with those of Dr. Bielefeldt. The assigned categorizations agreed for 11 teachers, with 3 placed into different categories. One of these was already noted as a borderline case due to inter-rater disagreement during the second iteration. The three cases with disagreement were discussed and ultimately resolved though one instance of my code changing to Dr. Bielefeldt’s code and two instances of her code being changed to reflect mine.

Figure 8 details the percentage representation of each code, showing A1 as the most common with 8 teachers assigned this code, and B1 as the least common with only one teacher. A1 represents teachers who believe they integrate EESI in their instruction and their personal understanding is aligned with the targeted understanding of the researchers, which is grounded in the literature. This flowchart details some important takeaways regarding the codes assigned to the teacher interviewees. First, it is notable how all three teachers applied B codes were engineering teachers, while non-engineering teachers were not coded with either of the B codes. Furthermore, 2 out of the 3 teachers assigned the A2 code were engineering teachers. It should also be noted that, after combining the teachers with B codes with those with A2 codes, 5 out of the 6 teachers were male. Among the 6 female teachers interviewed, five were in category A1. This aligns with previous research which found that ethics are more commonly implemented by female college instructors than male college instructors (Bielefeldt et al. 2018). Figure 9 indicates the previously shown graph of the realtionship between FRL and graduation rate, however each teacher interviewed has been included on the figure. The teacher interviewees correspond to the school that they teach at, and their assigned code is shown. Note that not all teachers are represented, as some schools have not yet seen a graduating class.

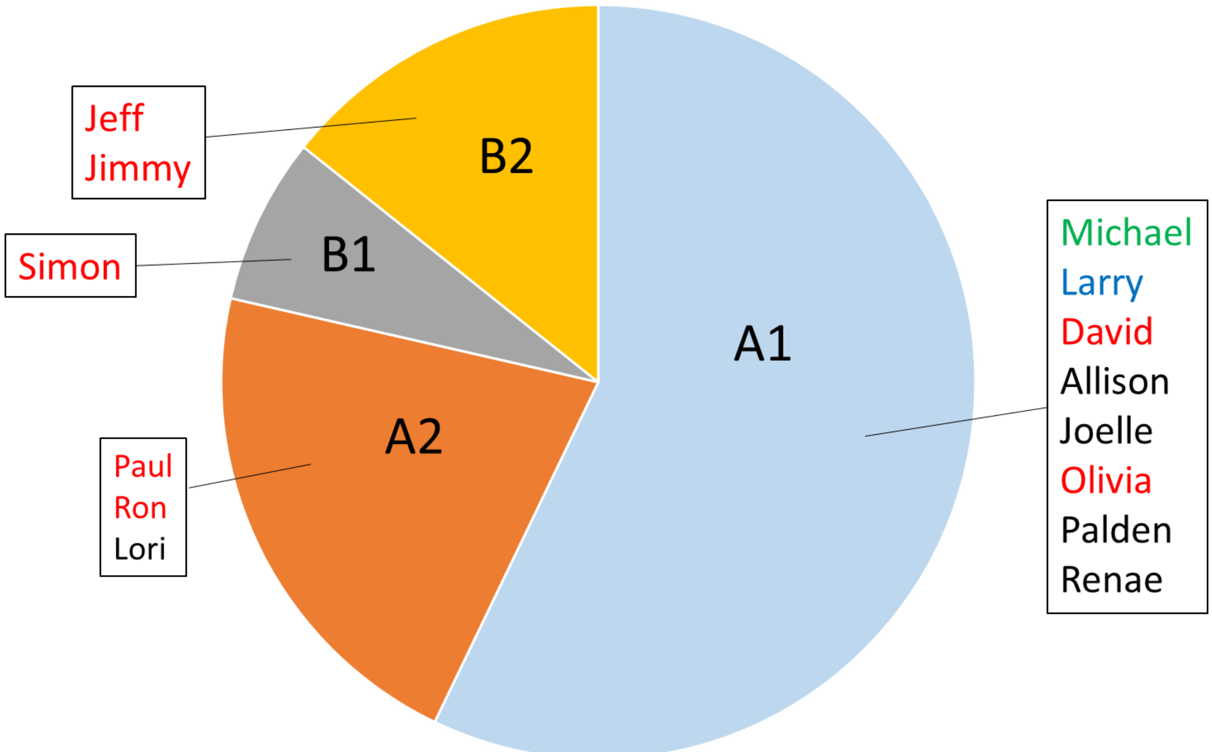

Figure 8. Categorization of interviewed teachers regarding EESI instruction. Names in red text = engineering, black text = science, green text = computer science, blue text = mathematics. A1 = teacher believes they integrate EESI and their understanding aligns with research, A2 = teacher believes they integrate EESI, but their understanding does not align with research, B1 = teacher does not believe they integrate EESI and their understanding aligns with research, B2 = teacher does not believe they integrate EESI, but their understanding does not align with the research.

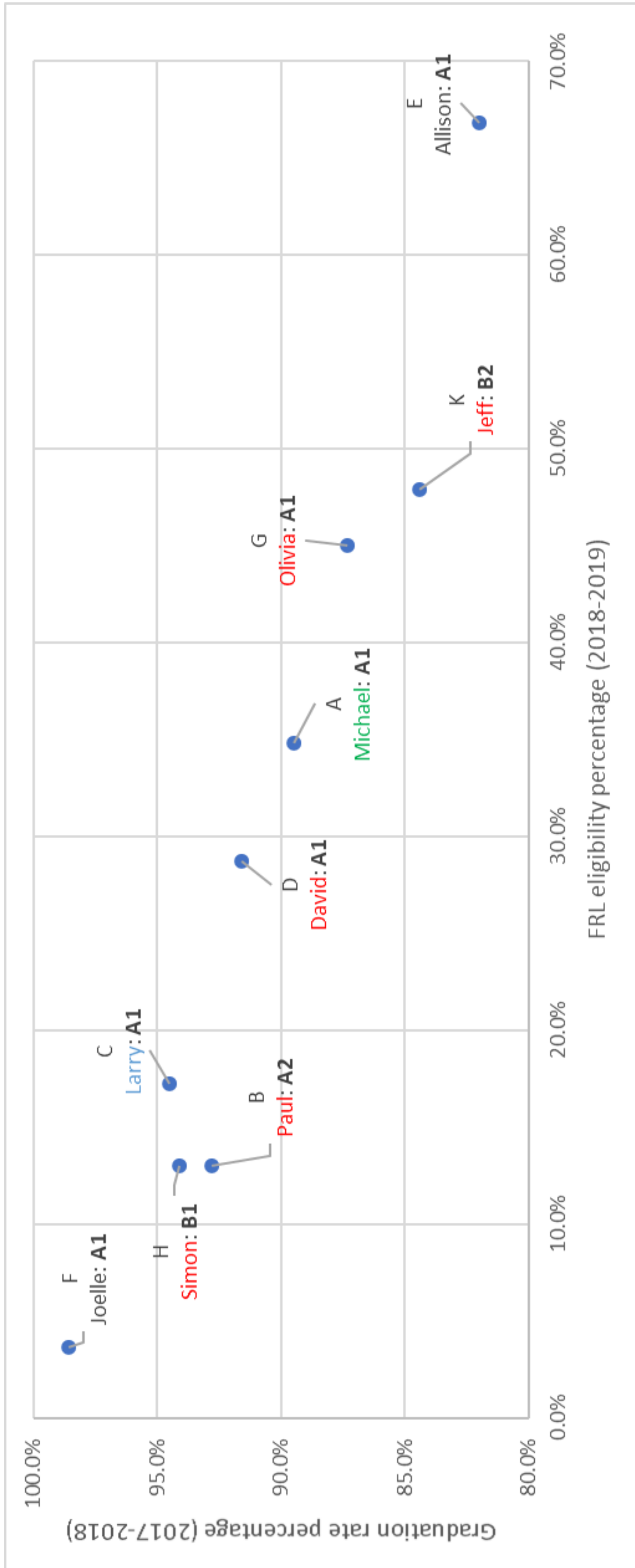

Figure 9. FRL eligibility versus graduation rate with assigned codes.

4.6 Research question 3: Importance

RQ3: How do high school teachers engaged with engineering/STEM view the importance of environmental/societal impacts and/or ethics integration?

The interviewed teachers often discussed importance on their own without prompting (such as Michael and Larry), and the specific follow-up questions on importance was not explicitly asked in all of the interviews. Most commonly, the follow-up question was asked after interview question 8 (about 30 and 45 minutes into the interview).

Similar to the range of responses to the ethics question that relates to research question 2, the teacher interviewees had varied perspectives regarding the importance of environmental/societal impacts and/or ethics implementation. Below are some examples detailing both topics and the range of responses.

A quote that reflects the importance of EESI inclusion from a science teacher follows, including the interview prompt that led to her response, is included below:

> Interviewer: So, do you believe that's important thing to include these topics being social and environmental impacts of technology in K12?
>
> Teacher: It's important, super important, because these are issues that people are going to be voting about, making decisions as members of society. So, I think it's super important, but I also think it's important that the teacher teaches. It's important we teach the science and allow students explore arguments on both sides, but that we allow students to develop their own opinion and we give them that freedom to do that. And in encouraging them to have conversations with their parents. In the work I assign, it allows their parents to have a voice in the

> process as well. And because I give the parents a voice I don't have issues with parents being upset about topics that I am teaching because they are given the opportunity to talk about their family values and their personal values around that with their child. *Joelle, science (biology) teacher, regarding ethics implementation*

To note, Joelle examines why inclusion of these topics is important since her students are, or will, be voting on impacting issues and need to be informed and responsible in doing such. She also explains that it must be done in a conscious manner. Her detail regarding the need to prioritize material is similar to other teacher's considerations while highlighting another obstacle regarding public perception. Yet despite this recognition, she is also able to explain how she overcomes this obstacle though increasing communication with parents.

David, an engineering teacher, began talking about EESI integration without prompting near the beginning of the interview. His statements seemed to reflect that he found these issues very important, and so the follow-up question on importance was asked at that early point in the interview. David responded with a nearly 2.5-minute answer, a subset of which is shown below:

> Interviewer [12 minutes]: So, to follow up on [previously talking about ethics] .... Do you think it's just important to include some social impacts or consideration in K12 education?
>
> Teacher: I absolutely do. And the reason I do, especially in engineering, is so often in engineering the question is asked 'can we do this?' And it seems often times that is the only question. And I think the question of 'should we do this?'

> should be tied into that as well. And so, the discussions [in class] on should we do something versus can we do something tend to be more rich. It's something that I'm always interested in, as both questions are relevant. There are questions when it comes to materials and how to process them, and there are questions about the environmental impact of the materials you are using. Both are important. *David, engineering teacher, regarding ethics implementation*

Similar to Joelle, David considers ethics implementation to be critical in K12 engineering/STEM education. And similar to Joelle, he recognizes that ethics could impede his pedagogy, however finds a balance of material and ethics. David describes a different reason EESI is important in comparison to Joelle, focusing on a perspective that as future engineers they should be concerned with whether or not some projects should even be done. Later near the end of the interview when asked if he would "like to share any other thoughts about engineering in K12 education, [etc.]", David reiterates importance and describes a different reason for importance:

> So, [ethical implementation] is something that I think has a lot of value. And just given that I teach has a huge emphasis on social impacts and ethical impacts and environmental impacts, I can see the value in that students really get into it. They personalize it a lot more. They care about it a lot more when there's ethical considerations incorporated into it. And I feel like I'm recognizing that more as I'm processing and talking it through with you. And it certainly is making me think "Hey, I could have a quick conversation in these different areas in my classes, that would be a great way to start things off." And I think that they would have a lot more buy-in in the content if they're thinking about "What are the impacts of

that?" So, I think that it's a really important thing to incorporate. I don't think that it's difficult to do. And I think it would help improve student engagement with just a little bit of conversation around that. And then that could be a way to start things, but that conversation doesn't need to end as an introduction. It can happen informally with students throughout the time that they're doing the work on that. So, I think it's a valuable thing to include in any class and probably every unit. *David, engineering teacher*

In this case, David indicates that EESI integration helps make things interesting for students and therefore motivates their learning.

A somewhat different perspective on ethics implementation comes from Paul, an engineering teacher:

Interviewer: Well, do you personally believe that K12 engineering programs should integrate ethics?

Teacher: Yeah. When you are just doing your homework or class assignments, if you have a kid who is going to copy, there is an ethical dilemma between the student and academic dishonesty. And the same is true in engineering. If you fudge a number and it comes back to that design that you forged a number or lowered a factor of safety in the calculation just so you don't have to go through the reiteration again, that's an ethical issue. Those are little things that actually could matter and you [the teacher] are responsible just getting [the students] to think that their purpose is providing something for the public in a safe and effective way. Essentially what engineering is. *Paul, engineering teacher, regarding ethics implementation*

Paul's perspective is a noteworthy one, as he gives examples of microethics that directly relate to his focus of engineering. And by detailing the link, he explains why it is important for these connections to be made in his students. Paul's explanation is similar to David's regarding importance. However rather than discussing the importance that engineers consider the impacts of their work explicitly, Paul emphasizes safe and effective engineers.

Another quote from a science teacher regarding the importance of implementing ethics is shown:

> [It's important to include ethics] because it is technology. It all depends on the program I guess. I would say our engineering program, while they just remodeled an entire wing of our school, I don't think they will be getting into many ethical discussions and the teachers will be focusing on how to manage the software or technology. But in a science course, like our biology classes with genetics and stem-cell research, they talk about the ethics. In my environmental science class I mentioned I think it's appropriate. You should always be talking to kids about ethics because it's like Spider Man. 'With great power comes great responsibility.' And this technology can be very powerful, it's important to make sure you are using it appropriately. We have seen this over and over again in history. This amazing technology is used, 'Look what I can do!' But should you really be doing that action with that technology? Nuclear power is a great example. So, we need kids that can think in terms of not what can you do but what should you do. *Allison, science (environmental) teacher, regarding ethics implementation*

Reflecting previously detailed perspectives, Allison believes that it is very important to provide ethical topics in her instruction so that her students may form their own understanding of ethics regarding science considerations outside of the classroom. Her perspective of a science course shows that these considerations go beyond explicit subject matter.

Finally, the below quote details a perspective of another engineering teacher who distinctly separated environmental/societal impacts from ethics:

> Societal and environmental impacts absolutely [should be implemented]. As far as ethics goes, I think it's worth considering. I think it is definitely important for K12 engineering programs to help students realize that every choice they make has repercussions. That's a good lesson for our kids to learn in every part of their life, but especially engineers because engineers have power that is magnified throughout their projects. And engineer of something small and inconspicuous could eventually be used to do something catastrophic or damaging to a certain subset of people. And that responsibility falls on the engineer to be wise about the choices that they make on the drawing board, because eventually these choices will be translated into concrete and steel and machinery. So, I think having a conversation about ethics would be worthwhile to have for sure. *Ron, engineering teacher, regarding ethics implementation*

This quote is noteworthy as it details how Ron believes that environmental/societal impacts is very important to integrate into engineering classes. However, he displays uncertainty on whether ethics should be implemented. This indicates a disconnect between these areas, while still emphasizing that some consideration of impacts is important to include. This is an example of a teacher’s personal understanding being misaligned with the targeted understanding of EESI.

To synthesize the 14 interviews conducted, there were a range of responses. The majority of teachers considered environmental and/or societal impacts important to include in engineering (or STEM) education. This is aligned with the fact that 78% of interviewed teachers were given the A code signifying that they incorporate environmental/societal impacts and/or ethics in their teaching. However, some teachers who considered engineering’s environmental/societal impacts to be important considered ethics to be less so, leading to the 21% representation of where the teacher’s personal understanding did not align with the targeted understanding. Overall, most teachers consider both environmental/societal impacts and/or ethics to be important to incorporate, which is reflected with A1 being the most commonly assigned code. Most teachers who incorporated EESI considered it to be important that their students understand the impacts their decisions can have on the environment and society and must conduct themselves in a responsible manner.

4.7 Research question 4: Obstacles

RQ4: What obstacles are perceived by high school teachers to integrating environmental/societal impacts and/or ethics?

Research question 4 explored teacher’s perspectives regarding obstacles to integrating EESI. Research in higher education found that many professors talked about obstacles to integrating ethics into engineering education, and it was of interest to see if similar or different obstacles would be described by high school teachers (Polmear et al., 2018; Canney et al., 2017). This research question emerged early in the interviewing process, as it was determined that the number of obstacles to implementing EESI in K12 engineering and STEM education exceeded the early conception and required qualitative coding. Moreover, each teacher interviewee identified at least one obstacle to the integration of these topics. Through the initial stages of the qualitative codebook, multiple obstacles were identified and defined through the teacher responses to the follow-up interview question, paraphrased, “what challenges and barriers do you perceive exist for societal and environmental and/or ethics implementation?” This question was not asked in every interview, given the nature of being a follow-up question, yet each teacher interviewee still touched on EESI obstacles.

The obstacles with the greatest representation in the interviews are defined below and have an accompanying example. Later in the study, these obstacles were further categorized as being either challenges or barriers per teacher interviewee. Challenges were defined as obstacles recognized by the teacher, yet are able to be overcome or otherwise addressed, while barriers were defined as obstacles that as-of-now cannot be overcome. The same type of obstacle might pose a challenge or barrier, depending on the particular teacher and their local conditions. Table 3 provides a summary of the emergent obstacles, with greater elaboration below.

Table 3. Obstacles to EESI integration identified by teachers.

Obstacles	Definition	Frequency
Time	Preparation time for EESI implementation in courses.	0.07 C
Curriculum	Availability in teacher's course curriculum to incorporate EESI.	0.36 C, B
Teaching Standards	Established standards that the teacher must meet impacts ESSI implementation.	0.36 C, B
Comfort Level	Implementing EESI is uncomfortable to teachers.	0.21 C, B
Perception	EESI is negatively perceived by students, parents, etc.	0.36 C, B
Difficulty	Students struggle to understand implemented EESI.	0.36 C, B
Lack of Content	There is a lack of EESI material or framework for teachers to utilize.	0.14 C

Table 3 indicates a few notable details. First, there is no single obstacle most common, rather 4 obstacles were identified by 5 out of the 14 teacher interviewees. The least common obstacle was "time", only identified by Olivia. The letter C corresponds to "challenge" whereas B corresponds to "barrier". This shows that five out of the seven obstacles we viewed as both challenges and barriers by interviewed teachers. Furthermore, all obstacles were perceived by at least one teacher as a challenge. Below are the definitions of each obstacle and example quotes from the teacher interviewees.

<u>Time</u>: This obstacle represents the time it takes a teacher to prepare for classes or subjects, including but not limited to, time it takes to learn about EESI and how to best implement related topics into a teacher's pedagogy.

This quote comes from Olivia, a former engineering teacher who also taught science courses:

> I think the biggest complaint with teachers is that there's not enough time. 'I don't have time to read those three articles.' Well, first I have to find those three articles, maybe I am unsure about whether those articles exist let alone find them. I think that is one of the biggest factors. A teacher in my school teaches 4.5 hours a day and gets 1.5 hours to plan. That means you are grading one hundred and eighty pieces of work and planning the next 4.5 hours for tomorrow in 1.5 hours. So, there isn't enough time to really do that kind of work [regarding ethical implementation]. I think there are more and more resources available but sometimes it becomes really daunting and overwhelming to the teacher because there is just so much there. *Olivia, former engineering teacher, regarding time as a **challenge**.*

This quote regarding time to prepare curricula highlights the high school teacher perspective on just how long this process may be. Despite this, Olivia perceives that this may be overcome with resources available to teachers. It should be noted that Olivia entered an administrative position, and the understanding the perspective of such individuals is considered as possible future work.

<u>Curriculum</u>: Some teachers perceived that the amount of content in their curriculum, self-imposed or related to established school/district expectations, allowed for little availability to implement EESI.

Another quote from David regards his perception on obstacles to EESI implementation:

> I think that the biggest constraint and challenge is time [meant as curriculum time], you are focusing on your content. You are thinking 'I want to make sure

> that students learn all of this information', and so it's wrestling with do I have enough time to go into the 'why'. I can say this as a teacher, I'm assuming someone has already addressed the 'why' because they are already doing this. So, let's just focus on 'Well, how are they doing it? And what would the next step be?' Rather than 'How are they doing it? And should they do the next step?
>
> *David, engineering teacher, regarding curriculum as a **challenge***

The obstacle of curriculum availability is reflected in existing papers pertaining to engineering education (Polmear et al. 2018). This details how this obstacle is apparent at multiple levels of engineering education. Regarding this example, David explains how he addresses this obstacle by balancing subject material and ethics implementation appropriate for his courses, hence why it is considered a challenge.

<u>Teaching standards</u>: Established teaching standards were viewed as an obstacle to EESI implementation by some teachers, either through the lack of structure regarding these topics or by limiting the level of implementation.

The below quote regards Allison's perspective on teaching standards:

> Well the current policy of standardized testing is a major roadblock. Because there's nothing in our standardized tests that addresses ethics, whether someone has a general understanding of what it means to have an ethical dilemma. There is no crossover, even in our civics classes. I just don't think that the curriculum is allowing to let us raise and teach a generation of critical thinkers who can basically agree to disagree. And that is because of the constraints of 'I need to make sure they do well on the SAT.' There is nothing on the PSAT or SAT about

> being a civically-minded person. But if [the students] don't know the three branches of the government, we [teachers] are done. *Allison, science (environmental) teacher, regarding teaching standards as a* ***barrier***

This quote from Allison details that the standards she faces as a teacher impacts what she can and can't include in here courses. While she is applied the A1 code signifying that she incorporates EESI, the obstacle of teaching standards is one she may view as currently impassable, as there is no applicable high school standardized test that incorporates ethical topics. And this obstacle limits the extent of her EESI integration.

<u>Comfort Level</u>: The implementation of EESI is viewed as being uncomfortable to some teachers, with reasons including but not limited to a lack of understanding and practice in implementing these topics or personal beliefs regarding their implementation. Simon, generalized as an engineering teacher, speaks on how comfortability among teachers may impede EESI:

> I think there is an issue with buy-in. I think you would have to convince teachers who are physicists, who love the physics or engineering. I think it might be somewhat difficult to convince them that it is important to address ethics which may be a topic they are not familiar with, and don't feel qualified to include. So, I think there's that issue as well. *Simon, engineering teacher, regarding comfort level as a* ***barrier***

Individuals without engineering training are perhaps more hesitant around their knowledge of engineering ethics. For example, Ron noted," other teachers I believe have engineering backgrounds. So, I don't know if I have any right to say what

engineering is or is not or what should be included in engineer class versus what is not."
The quote above is considered to be an example of a barrier as Simon does not offer a solution or way to overcome this obstacle.

This obstacle, identified by the high school teachers, is similar to an obstacle described by some college faculty in engineering (Canney et al. 2017; Polmear et al. 2018). One example quote, from a research study analyzing college faculty perspectives on engineering education, details: "Without experience of their own, engineering educators can have difficulty contextualizing ethical and social concerns and not feel comfortable covering issues that students will encounter in practice." (Polmear et al., 2018)

Perception: The implementation of EESI has possible negative perceptions from the students, their parents, political culture, and/or religious culture may hinder a teacher's integration of these topics.

David identified this obstacle after further consideration:

> One very small, very small barrier is that with some ethical questions, if you get into things that are very controversial in our current culture, it would be wise to inform parents of this, inform administration of this. I have never run into any issues there. *David, engineering teaching, regarding perception as a* ***challenge***

David perceives a potential issue but has not experienced it himself. Moreover, while he calls it a "barrier", he advises how it could be addressed through increasing communication between teachers with student's parents and administration, leading to it being considered as a challenge. In other quote, Ron was able to contrast two different teaching jobs, but still described imagined difficulties around perception:

> Yes, absolutely [there are obstacles]. Any time there is a controversial topic. It seems ridiculous that environmental impacts are a controversial topic, but it is. In my particular school, and in my network, we are very forward looking and so we are able to have thoughtful, productive discussions where we can see both sides of an issue. But I feel that in other districts, including even the one that I was in previously, because of political connotations as well as people come from different political stances and that impacts whether or not they want to engage in particular conversations, they think ethics and societal environmental impacts and engineering might potentially be one of those. I can just imagine a parent coming in and saying, "Why are you telling my son that…?" Yeah, I can just imagine that scenario playing out anytime a topic is controversial. *Ron, engineering teacher, regarding perception as a **barrier***

Something to note regarding this example of perception is that it's unclear whether the perception of potential pushback is stronger than the actual risk. Ron does not go into depth on the possible consequences of addressing these "controversial" topics, however he places notable weight on the backlash he could face as an instructor. Another example of this obstacle came from Larry, which also indicated concern with parent responses:

> I think quite honestly it's the parents who aren't there to hear the nuances of how it's approached in class. …And, you know, that that parent going to superintendent or school board or a principal and saying you know

> misunderstanding what the teachers' [intended]….. But you know that's for me. That's the thing that keeps it from being fully authentic and really digging into these controversial ideas and challenging our paradigms in a classroom setting.... I wish I had a nice answer to [addressing this obstacle] … I guess my best bet and advice for [overcoming] that would be keeping people informed ahead of time and not having them be shocked. *Larry, mathematics teacher, regarding perception as a* ***challenge***

This quote is very interesting, as initially it is being set up that Larry views perception as a barrier. However, after being prompted for any advice regarding this obstacle, he elaborates how this may be addressed with increased communication. This draws similarities with David's approach at overcoming perception, indicating a commonality in how this obstacle may be addressed.

<u>Difficulty:</u> Teaching EESI to students is challenging, with regards to the student's understanding of the material.

An example of difficulty was described by Michael during his interview:

> My experiences I've had as a teacher, which blows me away, is that the political leadership in America really either consciously or subconsciously affects the way our students approach their vision of the world. I'm finding that our students are not understanding a good sense of what is right and wrong because they are getting inundated with things that occur that really blur the line. And I find it concerning because I'm having to overcome that there is plenty of examples in our society of people questioning the idea of science being true or not. Yet you

> have students who get this idea of ‘what’s the problem with not telling the truth?’ It’s hard for me as a teacher to know what to do. I think one person can create some momentum, then others get on and those other people spread or reinforce that idea. So, I think my biggest thing is that our students are having a hard time understanding what an action means to be ethical. *Michael, computer science teacher, regarding difficulty as a* ***barrier***

This obstacle, regarding the difficulty in teaching students about ethical topics, is reflected in existing work at the higher education level (Polmear et al. 2018). What is notable here is that Michael forms the link between difficulty and political leadership, and how actions taken by those in a leadership position has far reaching consequences to his students. Another example of difficulty in teaching ethics is shown through a quote from Olivia below:

> To have a conversation with a bunch of high school kids, we’re talking about, [a teacher] can’t show up on the first week and be like “Hey, we’re going to talk about this today. Get in a circle.” You need those kids to trust each other. You need to have been doing all kinds of things in the two months prior to that big charged conversation before you’re able to really have people sharing their beliefs on it and feel comfortable doing so. *Olivia, former engineering teacher, regarding difficulty as a* ***challenge***

This quote shows another difficulty involved with teaching students about ethics, in that they must be familiar and comfortable around each other. Separate from teachers being uncomfortable regarding ethics, students must be able to trust each other to where they can openly address ethical issues in a group environment. This is considered to be a challenge as Olivia describes how this can be addressed by promoting student interaction in advance of an ethical discussion.

Lack of Content: Implementing EESI may be obstructed due to a lack of corresponding material a teacher can utilize or base their instruction off of.

An example of this obstacle is detailed below, from Jeff who is an engineering teacher:

> The nice thing is [a teacher] does not need any fancy equipment to teach ethics. You don't need a shop with special tools or anything like that. I think that maybe the barrier would be having, at least for me, good material to use… I just make my own lesson plans, and I know there's obviously stuff out there that you can find. And I've had some success just Googling engineering plans for various projects, and sometimes I find like gems out there. But mostly I end up making most of the lessons myself because they conform to what I think is the most important for my students to know. And I think that if I had access maybe to more material that taught ethics and taught it well and taught it in an interesting and relevant way, some of the examples that we talked about probably could include more [ethics] than for sure. *Jeff, engineering teacher, regarding lack of content as a* ***challenge***

This quote details how, for lack of much existing material, Jeff implements ethical topics himself through individually constructing curricula. However, his perception on this obstacle is deemed to be a challenge has he explains how this could be addressed through having access to more material, and material with greater depth. Another example quote regarding lack of content comes from Renae:

> I think one of the biggest challenges is that [ethics implementation] hasn't perhaps been done very effectively in the past. And I think as teachers, I can speak for myself and some of my close colleagues, we tend to reflexively teach the way that we were taught. And so, I think it can be challenging to try new things when it's never been modeled for you, or if there isn't like a gold standard to hit. And I think there's attempts nationwide if we look at what NGSS curriculum looks like, there is an attempt to bring that in. *Renae, science teacher, regarding lack of content as a* ***challenge***

This quote examines a different difficulty regarding a lack of appropriate content, where Renae identifies the lack of material that has been tailored to experienced teachers, ones who have established teaching practices. However, this is considered as a challenge as she mentions that there are attempts underway of connecting with these experienced teachers through examples such as the Next Generation Science Standards. This quote could also be linked to the first obstacle of time, as experienced teachers would require some amount of time to learn new material.

To conclude, it was determined that there was a very even representation of identified obstacles, with four obstacles having a frequency of 0.36: curriculum, teaching standards, perception, and difficulty. Furthermore, each teacher interviewee was able to identify at least on obstacle to integrating ethical topics, with some identifying as many as 4 (such as Olivia). This implies that each obstacle is not exclusive to the teacher interviewee, including "time" despite only being represented once. A larger sample size of interviewed teachers may support this assumption and is discussed in conclusions as possible future work.

5. Conclusion

5.1 Discussion of results

This research study indicates multiple results through qualitatively analyzing the transcripts of interviewed teachers. Due to the nature of there being two primary interview questions corresponding to EESI integration (Questions 5 and 8), teacher interviewees answered these questions without knowledge of their connection. This led to a wide range of explanations and examples regarding their perceived integration, which were analyzed through the usage of the qualitative flowchart. Despite there being a greater number of male teachers interviewed (8 male teachers, 6 female teachers), all three of the teachers coded with the B code, indicating that they did not believe they necessarily integrated EESI, were male. Alongside this, five out of the six female teachers interviewed were assigned the A1 code, which indicated that the teacher interviewee implemented EESI in their teaching with an understanding that aligned with environmental/societal impacts being among the ethical issues relevant to engineers. These results echo the previous research finding that female college instructors are more likely to implement ethics in engineering courses (Bielefeldt et al. 2018b). It is also interesting to note that two of the three teachers applied a B code detailed how they were comparatively new to teaching, having come from an engineering profession. This indicates that EESI integration is also influenced by experience prior to engaging in teaching and/or the relative inexperience as a teacher.

When asked about the importance of environmental and societal impacts and/or ethics in K12 STEM education, teacher interviewees gave responses that ranged from believing environmental and societal impacts important, ethics important, or both are important. It should be highlighted that despite this range, no teacher interviewee considered neither to be of some importance regarding K12 education. This included the teachers who did not believe that they integrate either concept into their courses. Where teacher perspectives varied was whether ethics should be included in K12 engineering education.

Another important takeaway is that, when prompted, each teacher interviewee was able to identify at least one obstacle facing EESI integration. A total of seven obstacles were identified by the teacher interviewees. These obstacles were defined and divided into two categories: challenges and barriers. Challenges were defined as obstacles that were able to be overcome or otherwise justified regarding EESI integration and were more represented among teachers applied A codes. Teachers in the A group, while recognizing challenges they face, are able to implement EESI regardless. Barriers were defined as obstacles that are currently impassable and were represented more among teachers assigned the B codes. These barriers were described, with some teachers identifying them to be the reason for their lack of EESI integration. However, challenges were not exclusive to teachers applied the A codes, nor were barriers exclusive to teachers applied the B codes. As previously mentioned, Allison, applied the A1 code, indicated that teaching standards acts as a barrier to EESI integration as it limits the overall scope of ethics she wishes to integrate. It's important to note that obstacles such as "perception" were identified across teacher transcripts and may be considered either challenges or barriers. This difference highlighted how some obstacles were more common than others and were perceived in different ways by the teacher interviewees.

5.2 Future Work

Given the narrow time frame to accomplish this study, there was a lack of analysis regarding the pedagogy teachers used to integrate EESI in their classes. This can be expanded upon in the future and compared to findings in higher education. Themes that could be included in this analysis may be how pedagogy approaches correspond with integration (or not) of EESI, and whether a teacher’s pedagogical approach of integrating EESI is further influenced by the school/district/state they teach in.

This research study focused only on interviewing teachers in the state of Colorado. One teacher interviewed, Paul, contrasted his previous teaching experiences in Pennsylvania with his current teaching in Colorado. It is unclear if these differences were due to state-level influences or the specific school he taught at. Future work could involve interviewing teachers in other states. States have different educational standards pertaining to public schools, such as computer science being a requirement for public high schools in Wyoming (“Computer Science Standards | Wyoming Department of Education,” n.d.). Further regarding expanding this study, a survey could be designed and sent to high school engineering and STEM-based teachers throughout the United States. A survey would be more efficient in gathering general information from a greater number of teachers, adhering to a variety of state-specific standards, and could lead into identifying teachers appropriate for a follow-up interview to still examine teacher perspectives in greater depth. A survey would also represent teachers of the various subjects better, notably mathematics and computer science teachers which were underrepresented in this study.

Future work may be conducted by interviewing high school administrators and/or board members. This was identified through one of the interviewees having moved into an administrative position after their time as a teacher. This would provide the perspective of individuals involved with school and district systems, such as a STEM coordinator organizing the goals of a new engineering program in a public high school, which may be very insightful.

Another aspect of future work could be examination regarding K12 STEM-based teacher training, and whether their training includes ethical topics to be integrated in their curriculum alongside learning how to integrate these topics. This would be extended to teachers from various states to examine whether state standards have a notable impact on this training. One obstacle that was identified in the study was that teachers may find a lack of EESI material. A teaching module regarding EESI, to be implemented in engineering and/or STEM-based courses, could be created and publicly distributed for high school teachers. One avenue of disseminating this EESI teaching module is through the website TeachEngineering.org.

5.3 Conclusions and implications

Pertaining to the four research questions, the following conclusions were made. It should be noted that given the number of interviewed teachers (14), these conclusions may not represent a study with a greater scope, involving more teachers and representing additional states. First, most of the teacher interviewees viewed environmental/societal impacts and ethics as being separate from each other. This distinction was represented across all applied codes. For example, a teacher applied the A1 code, indicating that they believe themselves to integrate EESI, may still detail a distinction between environmental/societal impacts and ethics. This illustrates that there is a degree of uncertainty regarding the congruence of environmental and societal impacts alongside ethics within engineering. Furthermore, this indicates that high school engineering and other STEM-based teachers may require more training to understand how engineering ethics encompasses societal and environmental impacts.

The third research question, regarding importance of EESI integration, yielded that most teachers, regardless of personal implementation, believe that ethics should be incorporated into K12 education. Teachers however varied regarding whether ethics should be explicitly implemented in engineering education. As stated previously, some teachers believed that ethics should be carefully considered due to perceived obstacles, yet some provided (possibly unknowingly) examples of EESI. The implications of this further details the disconnect that high school teachers may have with EESI integration. However, given that each teacher interviewee believed that ethics should exist in K12 education, it is indicated that the perspective of ethics inclusion among high school teachers is generally favorable.

Each teacher interviewee was able to identify at least one obstacle to EESI integration. In some cases, similar obstacles were identified by multiple teachers, indicating that while these obstacles stemmed from each teacher’s personal perspective, they are not indicated to be exclusive. However, some obstacles were indicated to be determinant to a particular context, such as the represented school, district, or course type. For example, Allison, a science teacher at a rural school, identified teaching standards such as “No Child Left Behind” as an obstacle to EESI integration, drawing in the context of the school she teaches at school.

Finally, the majority of the high school STEM-based teachers who were interviewed implement environmental and societal impacts and/or ethics in their courses. Out of the 14 teachers interviewed, 11 were assigned A codes regarding their belief of integrating some measure of EESI. While possibly lacking the understanding they do so, there is evidence that measures are being taken that high school students are engaged with EESI. It should be noted though that this result cannot be generalized to Colorado high school STEM teachers more broadly, given the uncertainty as to the extent that these individuals are representative of this group. Therefore, it is uncertain whether or not most students entering college who were engaged with engineering (or engineering topics) in high school have some familiarity with the idea that engineers consider societal and environmental impacts. Furthermore, these students may or may not consider these environmental/societal impact issues to be related to engineering ethics. This study represents a first step to understand teacher perspectives regarding EESI integration into K-12 settings.

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Appendix A: IRB approval letter for study

Office of Research Integrity
UNIVERSITY OF COLORADO **BOULDER**
INSTITUTIONAL REVIEW BOARD

Institutional Review Board
563 UCB
Boulder, CO 80309
Phone: 303.735.3702
Fax: 303.735.5185
FWA: 00003492

APPROVAL

08-May-2019

Dear Angela Bielefeldt,

On 08-May-2019 the IRB reviewed the following protocol:

Type of Submission:	Initial Application
Review Category:	Exempt - Category 2 -
Risk Level:	Minimal
Title:	Ethics and Societal Impacts integrated into K12 Engineering Education
Investigator:	Bielefeldt, Angela
Protocol #:	19-0263
Funding:	None
Documents Approved:	19-0263 Protocol (8May19); Interview - teachers; Recruiting Email - Higher Ed; 19-0263 Consent - Higher Ed (8May19); Interview - Higher Ed; Teacher Recruit Email Snowball ID; Recruitment email - teachers; 19-0263 Consent - Teachers (8May19); Higher Ed Recruit Snowball;
Documents Reviewed:	Protocol; Jake Lewis CITI; HRP-211: FORM - Initial Application v8;

The IRB confirmed the Exemption of this protocol on **08-May-2019**.

You are required to use the IRB Approved versions of study documents to conduct your research. The IRB Approved documents can be found here: Approved Documents

In conducting this protocol you must follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,
Douglas Grafel
IRB Admin Review Coordinator
Institutional Review Board

Appendix B: De-identified teachers invited to study

Note, to properly de-identify invited teachers, only the status of the district/organization is shown. Removed information regards teacher's names, schools they teach at, names of districts or organizations, and email addresses used to contact.

District or Organization	Status	Engineering teachers invited	Non-engineering teachers invited	Teachers interviewed
a	Private	2	0	1
b	Private	1	0	0
c	Public	3	4	2
d	Public	0	2	0
e	Public	8	2	1
f	Private	0	1	0
g	Public	1	3	0
h	Public	5	1	0
i	Public	6	9	1
j	Public	4	1	0
k	Public	0	1	0
l	Private	0	1	0
m	Public	5	5	2
n	Charter	7	4	3
o	Private	1	2	2
p	Public	1	5	1
q	Public	0	1	1
r	Public	2	0	0
s	Public	0	6	0

Number of public schools`	69
Number of private schools	9
Number of charter schools	14
Engineering-focused	46
Science-focused	35
Computer Science-focused	7
CTE-focused	4
Mathematics-focused	2

Appendix C: Email invitation for research participation

Ethics and Societal Impacts integrated into K12 Engineering Education

Faculty / Staff Recruitment Email

Subject: High School Engineering Study

We are contacting you in the hope that you will agree to participate in our research exploring the extent to which engineering integrated into K-12 settings includes elements of societal impacts or ethics. We believe that you have knowledge of how engineering is integrated into K12 settings (such as via a dedicated engineering course, integrated into math or science classes, or informal programs).

We invite you to participate in an interview. The interview would last about 30-60 minutes and will be conducted over the phone or skype by a civil/environmental engineering student at the University of Colorado Boulder, Jake Lewis. Jake is conducting this research as part of his Master's thesis. The interview can be scheduled at a time that is convenient for you.

If you are interested in participating in the research or learning more, please email us back.

Thank you.

Sincerely:

Angela R. Bielefeldt, PhD, PE

Professor, University of Colorado Boulder

Angela.Bielefeldt@colorado.edu

http://www.colorado.edu/faculty/bielefeldt

Jake Lewis

Master's student, University of Colorado Boulder

jale4712@colorado.edu

Appendix D: Interview verbal consent form

University of Colorado
Boulder

Title of research study: Ethics and Societal Impacts integrated into K12 Engineering Education

IRB Protocol Number: 19-0263

Investigator: Angela R. Bielefeldt, Daniel Knight, and Jake Lewis

Purpose of the Study

The purpose of the study is to explore how engineering is taught in K-12 settings, including dedicated courses, integrated into math, science, and other courses, or via informal settings. We are particularly interested in the extent to which ethical and societal issues (ESI) are highlighted or integrated with engineering topics, and why teachers do or do not integrate ESI with engineering education.

We expect that you will be in this research study for 30-60 minutes as you participate in an interview.

We expect about 20 K-12 teachers and 20 engineering faculty/staff will be in this study.

Explanation of Procedures

Your involvement in the research will entail answering open-ended questions posed in a semi-structured interview. The duration of the interview is expected to last 30 to 60 minutes. We will schedule the interview at a time that is convenient for you. The interview will be conducted on the phone or over skype. Jake Lewis, a student pursuing his Master's degree in Civil Engineering at the University of Colorado Boulder, will conduct the interview.

We will **audio record** the interview. This audio recording will be transcribed.

You will self-select a pseudonym. This pseudonym will be linked to your transcript. In future publications of the research (e.g. Jake Lewis MS thesis, conference papers) information associated with your interview would be attributed with your pseudonym.

You will be asked to provide the names and email address for other teachers who would make good study participants. You may opt not to provide this information.

If you choose to provide this information, you can decide whether or not to give us permission to reveal your name when contacting these individuals.

08 May, 2019

IRB Approval Date

Voluntary Participation and Withdrawal

Whether or not you take part in this research is your choice. You can leave the research at any time and it will not be held against you.

Potential Benefits

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include catalyzing future research that would develop K-12 engineering educational materials that more clearly link socio-technical issues or integrating these issues into professional development for teachers.

Confidentiality

Information obtained about you for this study will be kept confidential to the extent allowed by law. Research information that identifies you may be shared with the University of Colorado Boulder Institutional Review Board (IRB) and others who are responsible for ensuring compliance with laws and regulations related to research, including people on behalf of the Office for Human Research Protections. The information from this research may be published for scientific purposes; however, your identity will not be given out.

Payment for Participation

If you agree to take part in this research study, we will pay you $50 for your time and effort after the conclusion of the interview. Payments will be made electronically as an eGift card to Amazon. Provide the research team with the email address where you would like to receive notification of this gift card.

It is important to know that payment for participation is taxable income.

Questions

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at Angela.Bielefeldt@colorado.edu or 303-492-8433.

This research has been reviewed and approved by an IRB. You may talk to them at (303) 735-3702 or irbadmin@colorado.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get information or provide input about this research.

Appendix E: Original and modified semi-structured interview scripts

Original script:

Ethics and Societal Impacts integrated into K12 Engineering Education

Teacher Interview Questions

1) Consent:

1a) Do you have any questions on the research based on the consent form that you were emailed?

1b) Do you consent to participate in this interview and have it audio recorded?

1c) Have you selected a pseudonym? If not, we can return to this at the end of the interview and/or you can email your preference.

2) Please describe how you have integrated engineering into your teaching

Are your currently or have you previously taught a dedicated engineering course?

Have you integrated engineering into math/science courses?

Have you taught engineering in any after school programs or other informal settings?

What grades do these programs reach?

3) What are your goals when you integrate engineering?

Make kids more excited about learning in general?

Motivate kids to be interested in learning math or science?

Inspire students to pursue careers in STEM or major in STEM in college?

Teach specific engineering ideas?

Prepare students for living in society that is widely impacted by engineering / technology?

4) Do you believe that kids develop a better understanding of the social and/or environmental impacts of technology through your teaching of engineering?

Do you think the program helps kids think about societal impacts as a key responsibility for engineers?

If not, why?

5) If and how do you explicitly integrate ethical issues?

Why or why not?

6) Do you personally believe that K12 engineering programs should integrate ESI? Why or why not?

Are they doing enough?

7) Do you have any other thoughts that you would like to share about engineering in K12 or ESI?

8) Would you like to provide the names of any other K12 teachers who teach engineering and/or engineering college faculty / staff who work with K12 that you recommend we interview? This is completely optional.

Thank you.

If we decide to invite this person to participate in an interview, do you give us permission to use your name and affiliation in our email inviting [INSERT NAME] to participate in an interview?

If 1C not answered above: Have you had a chance to select a pseudonym? If we describe information you provided or short quotes from this interview, the pseudonym would be used.

Thank you for your time. If you would like to see the transcript of this interview, my completed MS thesis, or manuscripts published from the research, please email me or Professor Bielefeldt.

Revised script:

Ethics and Societal Impacts integrated into K12 Engineering Education

Teacher Interview Questions

1) Consent:

1a) Do you have any questions on the research based on the consent form that you were emailed?

1b) Do you consent to participate in this interview and have it audio recorded?

1c) Have you selected a pseudonym? If you haven't, we can return to this at the end of the interview. You may also email me your preference.

2) Can you start by telling me about the classes you teach?

Additionally, do you mentor any programs?

3) Would you please describe how you have integrated engineering (topics) into your teaching.

Are your currently teaching a dedicated engineering course? Have you previously taught an engineering course?

Have you integrated engineering into math or science courses?

Have you taught engineering in any after school programs or other informal settings?

What student grades do you teach in these classes and/or informal settings?

{if not engineering, ask about computing, technology, problem solving more generally}

4) What are your goals when you integrate engineering topics into your classes?

Would you say this integration makes students more excited about learning in general?

Would you say that students become more interested in learning math or science?

Does this integration inspire students to pursue careers in STEM, or major in STEM in college?

Do you seek to teach specific engineering ideas?

Do you feel that students are prepared for living in a society that is widely impacted by engineering and technology?

5) Do you include the societal and environmental impacts of technology in your instruction?

If so, how do you include these topics?

Do you believe it is important to include these topics in K12 education? Why or why not?

6) Do you believe that students develop a better understanding of the societal and environmental impacts of technology through your teaching of engineering, or inclusion of engineering topics?

{ask if the interviewee answered that they include ESI in Question 5}

7) Do you believe that the classes you teach, (and/or programs you mentor), helps students think about societal impacts as a key responsibility for engineers, or those going into STEM careers?

If not, why?

Have you ever had any students share experiences or thoughts related to this?

8) Do you explicitly integrate ethical issues into the classes you teach (or programs that you mentor)?

Why or why not?

If so, how do you do so?

9) Do you personally believe that K12 engineering (or STEM) programs should integrate ethics and/or societal and environmental impacts?

Why or why not?

If not, do you have any recommendations for ways to effectively integrate these topics?

Do you believe that there is enough representation of these topics in K12 engineering education?

Are there any challenges or barriers to this integration?

10) Would you like to share any other thoughts about engineering in K12 education, ethics, and/or environmental and societal impacts?

11) Would you like to provide the names of any other K12 teachers who teach engineering, and/or engineering college faculty who work with K12, that you recommend we interview? This is completely optional.

Thank you.

If we decide to invite this person to participate in an interview, do you give us permission to use your name and affiliation in our email inviting [INSERT NAME] to participate in an interview?

If 1C not answered above: Have you had a chance to select a pseudonym? If we describe information you provided or short quotes from this interview, the pseudonym would be used.

Thank you for your time. If you would like to see the transcript of this interview, my completed MS thesis, or manuscripts published from the research, please email me or Professor Bielefeldt.

Appendix F: Rough and edited transcription examples

Example of initial transcription from Trint (rough):

[00:30:47] Gotcha. So what are some ways that you integrate these ethical issues into your classes.

[00:30:55] Well I think I gave you the examples from from the others three. The civil design a manufacturing aerospace and biotech. We when we talk about health I mean there's there's a bioethics unit so we're talking about that specifically. But when we get into genetics you know again it's talking about well we can't do these things. You know we're getting to the point where we can test whether somebody has a particular type of disease. So if we find that out early and we can do something to prevent them from getting that should we. And then then we go into questions that well you know what what do you consider a disease or disorder is you know lack of height. Is that a disease a disorder is a lower IQ that a disease or disorder is that's something that if you can prevent that should you. And those those get into some pretty interesting debates you know along with environmental engineering and bio remediation incorporating you know microbes to eat up oil spills and then what are the what are the impacts of those kind of things and that that's maybe less of a of an ethical thing. But there are ethics involved in everything I mean when you're talking about cleaning up you know brown spots or environmental disasters you know there's if there if there is some kind of an impact as a result of these microbes then you know you can have ethical conversations centered around that. So and we do. So I guess those are are a couple examples. But again it would take a while to go through every one of them about tech but every unit we we discuss something.

[00:32:42] Would you say that these topics then regarding ethics and greater societal and environmental impacts are largely brought up through lectures or presentations and then followed up by open class discussion.

[00:32:57] Generally the way I do it is I ask my students I would present the question and I before we have any kind of conversation at all. I ask them to look at both sides so they have to do research on both sides. And then if we have a debate and we do that various have important points in the biotech class. Sometimes I let them choose their side. Sometimes they don't. I give them a side to argue and but I tell them they need to understand both sides. The thing that I really want to teach is empathy that it's OK to have an opinion on one side and people do. I mean generally people aren't complacent. If they if they know enough about a topic they they will tend to lean one side to the other. But what I'd try to tell them is that you know you can. You can have a firm belief into one side. But I wanted to learn how to be empathetic towards someone else's point of view so that you can have a conversation and not just be entrenched and you can at least understand why they might feel this way you don't agree with it as long as you can understand why they might feel that way. And so that's that's really where I try to to lead students because in that there's all sorts of you know long term implications for that and probably the most clear one is just politically that it feels like Politically our nation has kind of lost empathy with understanding why someone might feel the other way.

Example of edited transcription:

Interviewer [00:30:47] Gotcha. So, what are some ways that you integrate these ethical issues into your classes.

Teacher [00:30:55] Well I think I gave you the examples from the other three, the civil, design and manufacturing, aerospace. And in biotech, we, when we talk about health, there's a bioethics unit, so we're talking about that specifically. But when we get into genetics again it's talking about well we can do these things. We are getting to the point where we can test whether somebody has a particular type of disease. So, if we find that out early and we can do something to prevent them from getting that should we? And then we go into questions, what do you consider a disease or disorder? A lack of height? Is that a disease or disorder? Is a lower IQ, is that a disease or disorder? Is that something that if you can prevent that should you? And those get into some pretty interesting debates, along with environmental engineering and bioremediation incorporating microbes to eat up oil spills and then what are the impacts of those kind of things and that's maybe less of an ethical thing. But there are ethics involved in everything. When you're talking about cleaning up brown spots or environmental disasters, there is some kind of an impact as a result of these microbes then you can have ethical conversations centered around that. So, I guess those are a couple examples. But again, it would take a while to go through every one of them in biotech, but every unit we discuss something.

Interviewer [00:32:42] Would you say that these topics then regarding ethics and greater societal and environmental impacts are largely brought up through lectures or presentations and then followed up by open class discussion?

Teacher [00:32:57] Generally the way I do it is I ask my students, I would present the question and before we have any kind of conversation at all, I ask them to look at both sides, so they have to do research on both sides. And then if we have a debate, and we do that at various different points in the biotech class, sometimes I let them choose their side. Sometimes I don't. I give them a side to argue, but I tell them they need to understand both sides. The thing that I really want to teach is empathy, that it's OK to have an opinion on one side, and people do. I mean, generally people aren't complacent. If they know enough about a topic they will tend to lean one side to the other. But what I try to tell them is that can have a firm belief into one side. But I want you to learn how to be empathetic towards someone else's point of view so that you can have a conversation and not just be entrenched, and you can at least understand why they might feel this way. You don't have to agree with it as long as you can understand why they might feel that way. And so that's really where I try to lead students because then there's all sorts of long-term implications from that and probably the most clear one is just politically that it feels like, politically, our nation has kind of lost empathy with understanding why someone might feel the other way

Appendix G: First iteration of qualitative coding, codebook

Themes	Name	Definition
Macroethical topics	Responsible conduct in STEM	Mentioned that responsible practices in engineering and STEM were considered by students.
	Societal impact	Mentioned that greater implications of engineering and STEM were considered by students.
	Environmental impact	Mentioned environmental implications or protection as being considered by students.
	Energy	Mentioned energy being considered by students.
	Cultural awareness	Mentioned that cultural norms, ideas, or context in a project as being considered by students.
	Health	Mentioned human health as being considered by students.
Microethical topics	Academic integrity	Mentioned academic honesty, plagiarizing, or any other iniquity with regards to student academics.
	Safety	Mentioned that students grasp or are introduced to the consideration of human safety.
	Liability	Mentioned that project or product liability as a student consideration.
	Stakeholder	Mentioned the implementation of stakeholder consideration to students.
	Respectful discourse	Mentioned that students of differing perspectives engage with each other in a respectful and meaningful way.
Pedagogy	Seminar	An open discussion between students, with variable amount of teacher input.
	Lecture	A teacher gives a planned talk.
	Discussion	A teacher utilizes small or large discussions between themselves and their students.
	Case study	A teacher incorporates an ethical activity.
	Presentations	Students present their work, work they contributed to, or have another's work presented to them.
	Debate	Students defend their ideas against a peer in a discussion.
	Project design	Students engage in developing and completing a project.
	Project constraints	Mentioned schedule, scope, context, or other consideration applied to a project.
	Design competitions	Students engaged in a competition that involved project design.
	Work on teams	Students work with their peers to accomplish a defined activity or project.
	Professional development	Students were involved with practical activities to gain experience.
	Hands-on learning	Interviewee mentioned that they prefer to assist students with solving their own problems.
	Hands-off learning	Interviewee mentioned that they prefer students to solve their own problems without their assistance.
	Critical thinking	Mentioned promoting critical thinking and problem solving skills that aligns with engineering topics.
	Practical application	The application of the STEM subject outside of the classroom is mentioned, or how to engage in real-world situations.
	Religious affiliation	The institution the interviewee teaches at is religiously affiliated, and promotes its mission statement.
Demographics	Economic disparity	Mentioned an economic disparity of students in their classroom with regards to the institution or the average representation.
	Cultural disparity	Mentioned a cultural disparity of students in their classroom with regards to the institution or the average representation.
	Gender disparity	Mentioned a gender disparity of students in their classroom with regards to the institution or the average representation.
	Racial disparity	Mentioned a racial disparity of students in their classroom with regards to the institution or the average representation.
Goals	Engagement	Mentioned wanting to engage students in STEM and retain students priorly interested in STEM.
	Interest	Promoting interest in students in STEM was detailed as a goal.
	Authenticity	Mentioned wanting students to have an authentic and rewarding relationship with the subject(s) they teach.
	Ethical development	Mentioned changes in student ethical reasoning and understanding.
	Ethical behavior	Mentioned students exhibiting ethical reasoning and behavior.
	Ethical assessment	Mentioned evaluating student ethical understanding.
	Improvement	Mentioned that ethics implementation in engineering, STEM, or K12 in general needs to be improved.
	Importance of ethical inclusion	Mentioned how it is important that students in STEM be engaged with ethical topics.
Barriers	Time	Mentioned that time and curriculum scheduling limits implementation of ethical topics.
	Teaching standards	Mentioned that teaching standards or an applicable system limits the inclusion of ethics.
	Uncomfortable	Mentioned teaching ethics as being uncomfortable to teachers, or teachers lack the training to incorporate ethics.
	Ease of integration in STEM	
	Perception	Mentioned that perception of either the students, their parents/guardians, or the public at large is a barrier to the interviewee incorporating ethical topics in their curriculum.
Other	NGSS	Mentioned Next Generation Science Standards.
	ABET	Mentioned Accreditation Board for Engineering and Technology.
	NAE	Mentioned National Academy of Engineering.
	PLTW	Mentioned Project Lead the Way.
	AP	Mentioned AP testing with regards to engineering and/or STEM.
	TeachEngineering	Mentioned the usage of TeachEngineering modules.
	Not applicable	Ethics or ethical topics were not taught or promoted by the interviewee.

Appendix H: Second iteration of qualitative coding, groups

Note that levels of agreement are detailed between myself and Dr. Bielefeldt, regarding inter-rater reliability.

Proponent of Both ESI and Ethics Integration:

Definition: When asked if they explicitly integrate ethics alongside ESI, interviewee stated that they do. Their level of inclusion is notable through their examples of implementation ethical topics, while still identifying challenges to implementing ethics. These interviewees do not have any barriers to their own ethical implementation because they are able to overcome or justify the challenges they perceive, and in turn have the awareness of factors against ethical implementation yet are still able to continue their pedagogical approach. Believes that ethics is very, or critically, important with regards to their STEM focus. Moreover, they perceive that ESI and ethics are related or congruent to each other.

David – strong agreement; both at top of this category

Micheal – same category but Jake at top and AB near bottom

Joelle – same category; Jake higher

Renae – agreement on category, but relative placement higher by AB

Allison – strong agreement

Larry – same category; different relative

Palden – Jake bottom of top; AB top of middle; distinction between soc/env in ENG ; agree in ENVS; will revisit after clarify middle category description / criteria

Proponent of Only ESI Integration:

Definition: When asked if they explicitly integrate ethics alongside ESI, interviewee stated that they do not. Their level of inclusion is variable, as they identify challenges to implementing ethics in their pedagogy and/or barriers that limit their scope of ethical implementation. These interviewees may incorporate ethical considerations evidence through their description of ESI inclusion, but do not view it as such. Due to these reasons, these interviewees may only incorporate ethics as anecdotes to the larger curriculum, rather than stand-alone units. In varying stages, these interviewees have trouble overcoming or justifying ethicals implementation with regards to their curriculum, school structure and expectations, or any other factor. May be unsure about how important ethics is in their STEM focus and/or the level to which it should be implemented (are/will implement ethics, the question is how much).

Lori – [disagree initially; Jake on border, Angie strongly in top category; did not converge after first discussion]

Paul – disagreement on categorization initially; 2nd from bottom of this category and AB had at bottom of top category; after discussion moving to top of middle category / borderline

Olivia – strongly agree between raters

Ron – strongly agree between raters

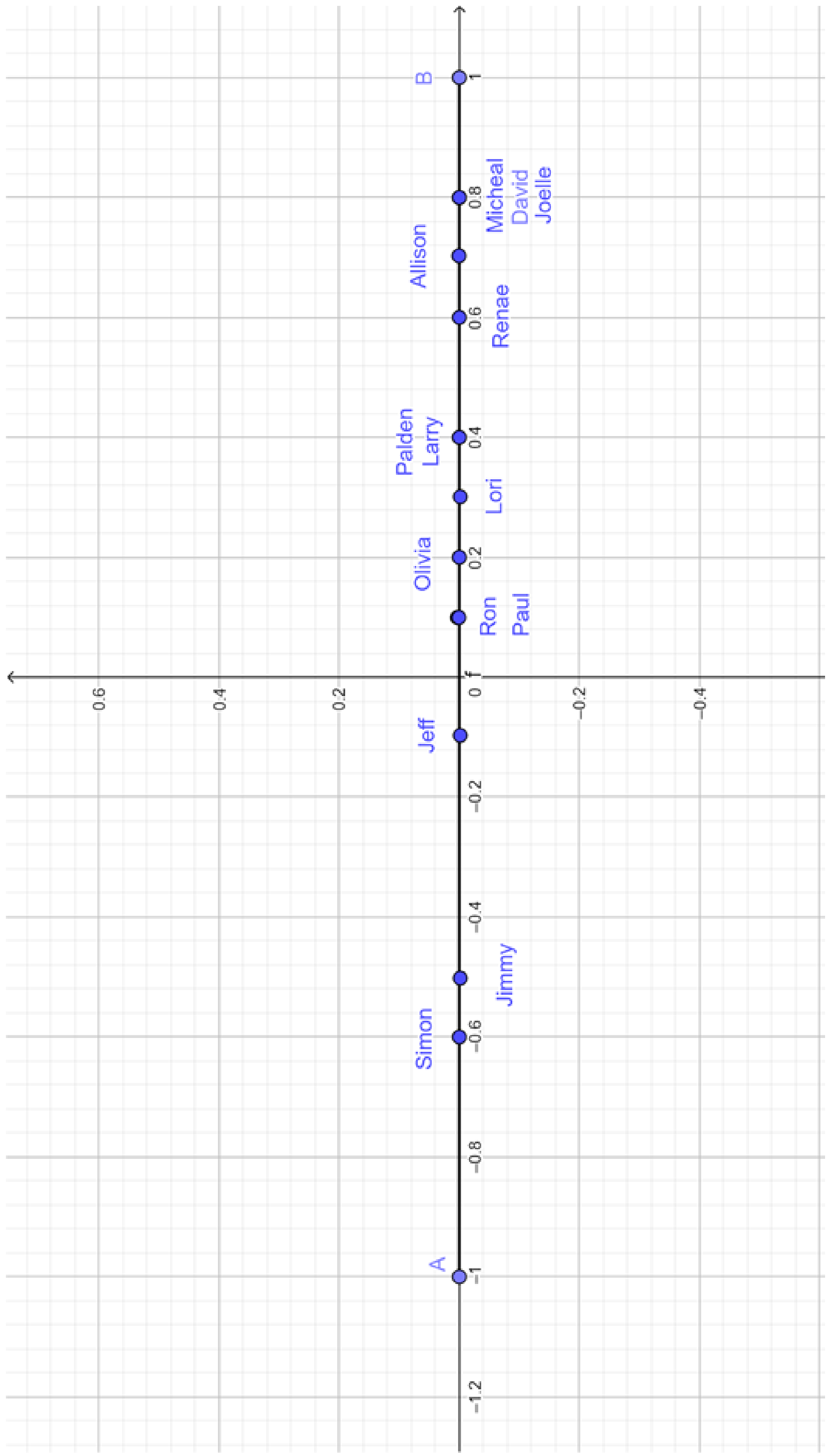
Jeff – generally agree between raters {category same; relative location now}

Does Not Teach Either:

Definition: When asked if they explicitly integrate ethics into their pedagogy, interviewee stated that they do not. Further evidenced with their limited ESI implementation. May actually discuss integrating societal and environmental impacts, however the key term "ethics" is stated as not being included. Discusses barriers rather than challenges to incorporating ethics, and for these reasons they do not plan to teach ethics and/or does not consider ethical implementation for their given STEM focus. Do not necessarily believe that ethical implementation in STEM is incorrect, however believes that curriculum takes precedence over ethics regarding their STEM focus.

Simon – strongly agree

Jimmy – strongly agree


B
Micheal
David
Joelle
Allison
Renae
Palden
Larry
Lori
Olivia
Ron
Paul
Jeff
Jimmy
Simon
A
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2